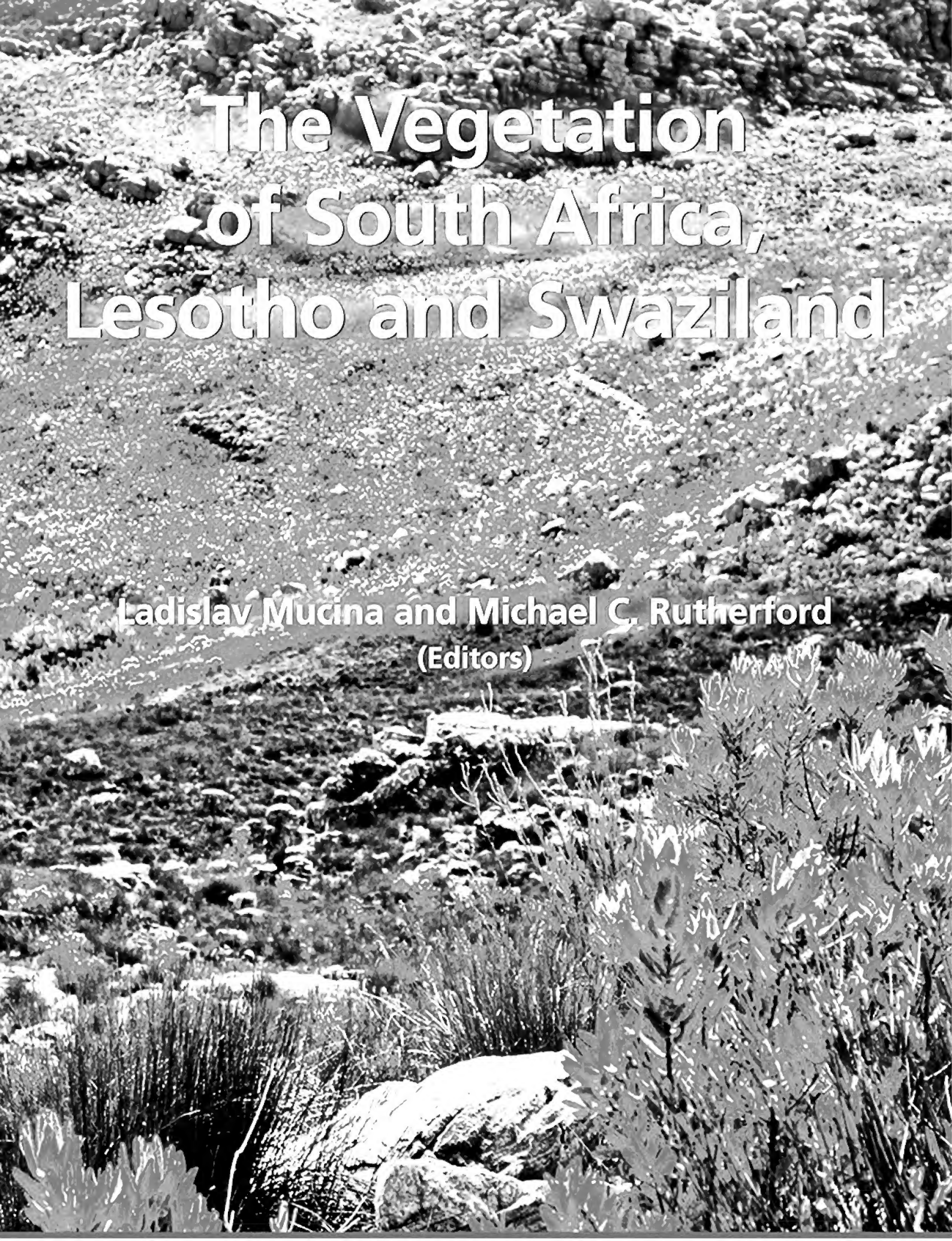

The Vegetation of South Africa, Lesotho and Swaziland

Ladislav Mucina and Michael C. Rutherford
(Editors)

STRELITZIA 19

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SOUTH AFRICAN
national
biodiversity
institute
SANBI

Pretoria

2006

STRELITZIA

This series has replaced *Memoirs of the Botanical Survey of South Africa* and *Annals of Kirstenbosch Botanic Gardens* which SANBI inherited from its predecessor organisations.

The plant genus *Strelitzia* occurs naturally in the eastern parts of southern Africa. It comprises three arborescent species, known as wild bananas, and two acaulescent species, known as crane flowers or bird-of-paradise flowers. The logo of the South African National Biodiversity Institute is based on the striking inflorescence of *Strelitzia reginae*, a native of the Eastern Cape and KwaZulu-Natal that has become a garden favourite worldwide. It symbolises the commitment of the Institute to promote the sustainable use, conservation, appreciation and enjoyment of the exceptionally rich biodiversity of South Africa, for the benefit of all people.

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Foreword

Why another vegetation map of South Africa, especially considering that Acocks (1953) *Veld types of South Africa* has served two generations of scientists so well?

One answer to this, and to most questions on the purpose of scientific endeavour, is that we live in a knowledge-driven society, where informed, environmentally sensitive and rational decisions are the cornerstones of sustainable socio-economic development. But more directly, despite the utility of Acocks's map for more than half a century, our knowledge base, technologies and demands for detailed spatial information on natural resources make a new, spatially detailed map and description of our vegetation both possible and necessary.

South Africa and the continent as a whole have set ambitious development goals for the 'African Century', goals which simply cannot be met without an underpinning of sound decision support. Such growth initiatives, infrastructure needs and wise land use demands were behind the establishment, in 2004, of the South African National Biodiversity Institute (SANBI), the successor to the former National Botanical Institute (NBI) which itself had roots in the Botanical Research Institute and the National Botanical Gardens of South Africa, established in 1903 and 1913 respectively.

The parliamentary mandate given SANBI through the Biodiversity Act of 2004 includes monitoring and reporting on the status of the Republic's biodiversity, the conservation status of species and ecosystems, and on the diverse impacts on these. Such reporting requires a detailed vegetation baseline and an understanding of the dynamics of constituent ecosystems. The production of *The vegetation of South Africa, Lesotho and Swaziland* (which includes the new Map) is therefore particularly timely, given the high expectations placed by our stakeholders on SANBI and our many partners in biodiversity science.

This volume marks yet another major milestone in the history of biodiversity knowledge development in southern Africa. Over the past two centuries, the process of discovery, description, evaluation and synthesis of information on and understanding of our flora and vegetation has followed a regular cycle. Benchmarks along the way include the early botanical explorations of Thunberg, Sparrman, Masson and others at the close of the 18th century, the publication of *Flora capensis* from the mid-19th century (Harvey & Sonder 1859–1860), the pioneer ecological studies of Marloth, Bews and Adamson in the early 20th century, and the production of the first vegetation map for the country by Pole Evans in 1936.

A new wave of field work and synthesis came with Acocks's 1953 map, and the stimulus to plant taxonomy anticipated by the launch of the *Flora of southern Africa* project in the 1960s. The taxonomic agenda of the late 20th century has focussed on regional floras (Bond & Goldblatt 1984, Retief & Herman 1997, Goldblatt & Manning 2000) and some major monographs (Van Jaarsveld 1994, Goldblatt & Manning 1998, Smith & Van Wyk 1998, Linder & Kurzweil 1999, Van Jaarsveld & Koutnik 2004). Towards the end of the 20th century, slow progress with the *Flora of southern Africa* project resulted in a decision to prepare a 'Concise flora of southern Africa' while a regional programme of taxonomic capacity building—SABONET—addressed the human and institutional resource needs in this field of botany. Significant results of these initiatives are illustrated in the two mega-volumes published this year—*Checklist of flowering plants of Sub-Saharan Africa* (Klopper et al. 2006) and *A checklist of South African plants* (Germishuizen et al. 2006).

Research on the structure and function of South African ecosystems received a significant stimulus during the 1970s and 1980s, through a network of major interdisciplinary studies in the Savanna, Fynbos and Karoo Biomes, leading to several comprehensive syntheses on these (Cowling 1992, Scholes & Walker 1993, Dean & Milton 1999). Cowling et al. (1997) drew together the findings of the surge of ecological activity during these two decades in the multi-authored *Vegetation of southern Africa*, a classic synthesis with few equals elsewhere around the globe.

The succession of field research and resulting taxonomic and ecological syntheses prompted the need for a new generation vegetation map and descriptive memoir. While vegetation surveys had been active through the later decades of the 20th century, they had been widely scattered and unco-ordinated—responding to the needs of conservation agencies and land use planners rather than to establishing an integrated regional synthesis. In 1996 the VEGMAP Project was initiated to prepare a successor to *Veld types of South Africa.*

Acocks's (1953) classic study was the last of the great, single-authored works on the flora or vegetation of South Africa. By the turn of the 20th century, South Africa had built an uncommon ability, by global standards, to bring together large teams of natural scientists to tackle national priorities. The power of electronic information management, while never able to replace the critical importance of humble field natural history observations, has nevertheless made possible the collection and integration of vast databases—not achievable just a few decades ago. In particular, the power of Geographical Information Systems has aided the immense task of integrating spatial information at widely differing scales and detail.

The task of preparing a new Vegetation Map fell to a succession of co-ordinators, and acknowledgement should be made to the initial work of David McDonald and Michael O'Callaghan. It soon became clear that a full-time commitment to the project was needed, and Michael Rutherford's wide experience in southern African vegetation science made him an obvious candidate. In assembling a team of about 100 contributors, further support in the huge task of synthesising diverse datasets was essential, and the wealth of experience of Ladislav Mucina, who had then recently arrived in South Africa from Europe, was perfectly timed.

The VEGMAP Project soon grew into a major intellectual and organisational challenge. The sheer volume of field data, the diversity of vegetation classification and mapping methodologies used, and the 10 000 species included in the survey data, extended the project well beyond its initial five-year timeframe. But the resulting map, released ahead of this descriptive memoir, is already finding wide application and great utility in both its hard copy and electronic formats.

SANBI can be justly proud of the achievements of its professional staff, and those of its many collaborating institutions, as it faces the demands of the new century. This volume, which includes the map, will most surely serve South Africa and beyond as effectively as its remarkable predecessor, Acocks's *Veld types*. The advantages of electronic information systems will allow more regular revisions to both the map and the memoir than was possible for *Veld types*, and users are encouraged to communicate with SANBI should they have suggestions on improvements to future versions of this study.

The continuing support of the national Department of Environmental Affairs and Tourism and of the Norwegian Government to this project, is gratefully acknowledged. Special tribute should also be paid to the many dozens of dedicated fieldworkers whose collective toil under the African sun is reflected in this remarkable volume.

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August 2006

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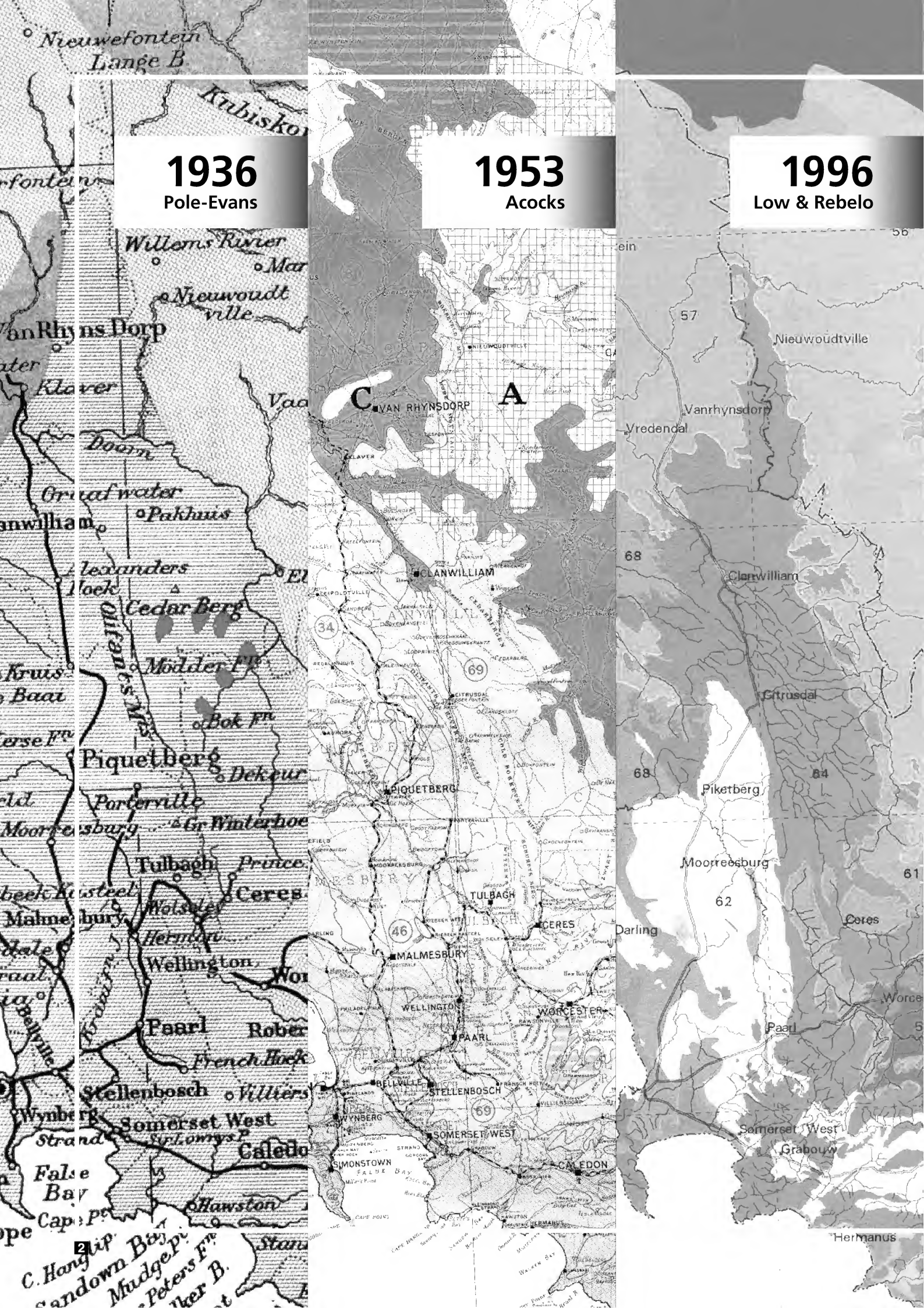
1936
Pole-Evans
1953
Acocks
1996
Low & Rebelo
Nieuwefontein
Lange B.
Willems Rivier
Nieuwoudt ville
Van Rhyns Dorp
Klaver
Doorn
Graafwater
Pakhuis
Alexanders Hoek
Cedar Berg
Modder Fn
Bok Fn
Piquetberg
Dekeur
Porterville
Gr Winterhoe
Tulbagh
Prince
Ceres
Wolseley
Hermon
Wellington
Paarl
French Hoek
Stellenbosch
Villiers
Somerset West
Caledo
False Bay
Hawston
C. Hanglip
Sandown Bay
Mudge Pt
Peters Fn
VAN RHYNSDORP
CLANWILLIAM
PIQUETBERG
TULBAGH
CERES
MALMESBURY
WELLINGTON
WORCESTER
PAARL
BELLVILLE
STELLENBOSCH
WYNBERG
SOMERSET WEST
SIMONSTOWN
CALEDON
Nieuwoudtville
Vanrhynsdorp
Vredendal
Clanwilliam
Citrusdal
Piketberg
Moorreesburg
Darling
Ceres
Paarl
Somerset West
Grabouw
Hermanus

2006
Current work

Introduction 1

Michael C. Rutherford and Ladislav Mucina

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Figure 1.1 Snapshots of the history of vegetation mapping in South Africa.

L.W. Powrie

1. Preamble

We present an up-to-date and comprehensive overview of the vegetation of South Africa and the two small neighbouring countries of Lesotho and Swaziland. This account is based on vegetation survey using appropriate tools of contemporary vegetation mapping and vegetation description. We aimed at drawing a new vegetation map that depicts the complexity and macro-scale ecology and reflects the level of (and identifies and reveals gaps in) our knowledge of the vegetation of the region. This is an extensive account of the vegetation of a complex and biologically intriguing part of the world, offering not only insights into structure and dynamics of the vegetation cover, but containing a wealth of base-line data for further vegetation-ecological, biogeographical, and conservation-oriented studies. Our Map and the descriptive account of the vegetation of South Africa, Lesotho and Swaziland targets not only scientific academia and the secondary and tertiary education sectors, but offers a powerful decision-making tool for conservationists, land and resource planners, and politicians as well as the interested public at large.

2. Mapping Spatial Complexity of Vegetation Cover

Vegetation mapping is one of the most important and most widely used tools to simplify spatial complexity of vegetation cover. In the past, floristic-based mapping was invariably linked to syntaxonomy (vegetation systematics) providing a classification system of vegetation in a mapped area. Thus the theory and methods of vegetation mapping has been dominated by the idea of the floristic-sociological approach to vegetation classification and its major schools known as the Braun-Blanquet School and Russian School in particular (see textbooks, chapters relevant to vegetation mapping in general vegetation science works and major review papers such as Gaussen 1961, Sochava 1962, Braun-Blanquet 1964, Küchler 1967, 1984, Ozenda 1986, Küchler & Zonneveld 1988, Faliński 1990–1991, Dierschke 1994, Glavać 1996, Crişţea et al. 2004 and Pedrotti 2004, to mention just a few). Currently vegetation mapping operates on a much broader theoretical and methodological platform by incorporating new approaches of remote sensing and spatial environmental correlation through GIS (Alexander & Millington 2000).

Vegetation mapping has enjoyed a long tradition in Europe, where at least four different 'schools' have been formed. The 'Stolzenau School' named after Stolzenau am Weser—a small town in Niedersachsen, Germany—has been associated with names such as R. Tüxen (the founder of a small research institute devoted to vegetation survey and mapping in Stolzenau), W. Trautmann, K. Buchwald and U. Bohn who definitely influenced the work of other central European (R. Mikyška, R. Neuhäusl, Z. Neuhäuslová, J. Moravec, J. Michalko, Š. Maglocký, W. Matuszkiewicz, H. Wagner and J.B. Faliński) and further afield also Japanese (A. Miyawaki and K. Fujiwara) and American (A.W. Küchler) vegetation scientists. Dierschke (1994) further recognised the so-called 'South French School' associated with names such as L. Emberger, H. Gaussen, R. Molinier and P. Ozenda. This school influenced mapping in southern Europe (S. Rivas-Martínez, F. Pedrotti and R. Venanzoni). The 'ITC School' emerged at the current ITC Institute in Enschede, the Netherlands, and became known for the early application of remote-sensing approach to vegetation mapping. D.C.P. van Thalen and I.S. Zonneveld (see Zonneveld et al. 1979) can be mentioned as prominent personalities of this school. The 'Russian School' has been particularly active at the Komarov Institute of Botany in St Petersburg (earlier also known as Leningrad). This institution is associated with great names such as E.M. Lavrenko, V.B. Sochava, S.A. Gribova, T.K. Yurkovskaya, G.M. Ladygina and I.N. Safronova. The specialist journal (*Geobotanicheskoie Kartirovanyie*) devoted to vegetation mapping is published by this research group. Undoubtedly the Europe-based vegetation mapping research groups influenced further dissemination of the vegetation mapping methodology and the initiation of mapping projects on other continents.

Among the major mapping achievements featuring vegetation on (sub)continental levels, rank: e.g. Lavrenko & Sochava (1954, 1956: former Soviet Union), Küchler (1964: USA), Niklfeld (1973: countries of the Danube basin), Horvat et al. (1974: Balkan Peninsula), Rzedowski (1978: Mexico), Beard (1979: Western Australia), Ozenda et al. (1979: western Europe), Miyawaki (1980–1989: Japan), Hueck & Seibert (1981: South America), Hou et al. (1982: China), Ozenda (1985: the Alps), Rivas-Martínez (1987: Iberian Peninsula), Brown (1994: southwestern USA and northwestern Mexico), Ladygina et al. (1995: Kazakhstan and central Asia), Blasco et al. (1996: tropical continental Asia) and Ni (2001: China). Two large international teams produced the monumental vegetation map of Europe (Bohn et al. 2003) and the map of circum-arctic vegetation (Walker et al. 1995, 2005).

A selective review of maps classified according to mapping scale was presented by Dierschke (1994) and the reader is referred to numerous bibliographies (mainly published in the journal *Excerpta Botanica*) featuring the products of mainly syntaxonomy-based vegetation maps.

For many logistic, developmental and historical reasons, the African continent has experienced only marginal interest of vegetation mappers. The vegetation of the continent has been mapped (as a whole) several times (Keay 1959, White 1983, Burgess et al. 2004), but its large extent (Africa is the second largest continent) and paucity of data did not allow for detail. Several larger regions (Wild & Barbosa 1968: area of the *Flora zambesiaca*) and countries (e.g. Barbosa 1970: Angola, Giess 1971: Namibia, Guillaumet & Adjanohoun 1971: Ivory Coast, Bekker & De Wit 1991: Botswana, etc.) have been mapped using traditional methods. Only recently has application of remote-sensing methods and GIS led to production of more detailed and credible vegetation maps (Frederiksen & Laweson 1992: Senegal, Du Puy & Moat 1998, 1999: Madagascar).

3. Vegetation Mapping in South Africa

The roots of vegetation mapping of the African subcontinent go back to the nineteenth century but at very coarse scales and using mostly very poor information (see review by Werger 1978). Even though the Botanical Survey of the then Union of South Africa was started in 1918, the earliest vegetation map of southern Africa (with some detail) can probably be regarded as that of Pole Evans in 1936 (the actual map is dated 1935). At least parts of his map were more detailed than the broad 'biome level'. Thus, for example, he distinguished three grassland types as well as three types of 'parkland' (savanna). He recognised 12 types of vegetation in total. This work was followed in 1938 by Adamson who mapped 14 types of vegetation in the region with different emphasis of detail, including six types in the 'semi-desert' and four in 'savanna' but only a single grassland type.

In 1953 a major milestone was reached with the publication of *Veld types of South Africa* by John Acocks in which he mapped 70 types of vegetation in South Africa, Lesotho and Swaziland. The scale of the printed map (1:1 500 000) allowed for unparal-

leled detail and was presented in a form that R.A. Dyer in his foreword described as 'a work of art'. His 1953 book was reprinted with photographs added and plant names updated in 1975 and again in 1988. It is ironic that most of his field data were collected after the publication in 1953 (Rutherford et al. 2003a) and were not incorporated in the later editions. They were, however, available for a revision of his *Veld types* but did not progress beyond an unpublished manuscript (with no map) for the western half of the country (Acocks 1979) shortly before his death in 1979. In a letter to a colleague in 1954 Acocks called his memoir '... a half-baked washout and a disgrace to the Division that was inept enough to hustle me into writing it before my data were complete enough even for a preliminary paper' (Hoffman & Cowling 2003a, b). A re-analysis of Acocks' data for the area of the Nama-Karoo Biome substantiated a number of his veld types while not upholding some others (Rutherford et al. 2003b). Despite Acocks' opinion expressed in 1954, his work became known as the most widely used published product in South African ecology over a period of more than five decades. White's (1983) mapping units within South Africa are less detailed than those of Acocks and he relied heavily on the work of Acocks for this section of his map.

The SAAB (South African Association of Botanists) map of Low & Rebelo (1996 and reprinted as a second edition in 1998) was initiated at a meeting held in Durban in January 1992. At this meeting it was decided that the new map was needed mainly for pedagogical purposes—a map which would essentially be a simplification of Acocks' map. To a large extent this simplification was carried out for the arid areas of Karoo and Namaqualand, often retaining some boundary lines of Acocks' veld types. Much of the Grassland and northern Savanna areas were also mostly simplified but often with different and smoother boundary lines than Acocks. Greater detail was added in the Kalahari areas and parts of the Fynbos Biome and much of the Lowveld area was totally revised. Acocks' Valley Bushveld, Spekboomveld and Noorsveld were reassigned to various 'thicket' vegetation types. A major advance over the Acocks map was the mapping of many patches of forest types. However, the net effect of the simplifications and additions was 68 vegetation units, i.e. slightly fewer than Acocks (Table 1.1). The 'SAAB map' thus consisted of a mixture of less detailed and more detailed parts relative to the map of Acocks. Low & Rebelo's (1996) map was furthermore made at a smaller scale than that of Acocks and it was printed at three different scales, namely 1:1 850 000, 1:2 000 000 and 1:3 880 000.

Even before Low & Rebelo's map was published in January 1996, it was clear that to substantially improve on Acocks' map would require a totally fresh start independent of his map and considering all available data (most of which—including most data of Acocks—were collected after 1953). There was also a realisation that for planning at regional and local levels, a much more detailed approach than that of either Acocks (1953) or Low & Rebelo (1996) should be implemented.

Vegetation mapping is a frequently used tool in nature and especially wildlife conservation practice in South Africa. Since successful, scientifically defendable running of both statutory and private conservation areas requires (by law) formulation and implementation of spatial management plans, vegetation has often been used to stratify land into 'management units'. Hence a large number of vegetation maps of small areas have been constructed. These maps were of great help to the VEGMAP team since in many areas this was the only viable information source of vegetation cover. Many of the local maps were published in local journals such as *South African Journal of Botany, Bothalia, Koedoe* or *Bontebok* or in series of reports (see for instance References in Chapter 14 on Coastal vegetation). Still more maps remain, buried in unpublished reports and management planning documentation of the provincial nature conservation bodies (CapeNature, Ezemvelo KZN Wildlife, Mpumalanga Parks Board, South African National Parks, etc.) and postgraduate masters and doctoral theses. It is beyond the scope of this chapter to list them all—they are, however, exhaustively referred to in particular chapters of this book.

Of great importance to our Project were published maps featuring larger portions of South Africa. They played, alongside the all-country maps mentioned above, a pioneering role in mapping vegetation of the subcontinent. Through the spatial extent of detail covered, distinction was earned by the contributions of Pentz (1945: former Natal Province), Edwards (1967: Tugela/Thukela River basin), Boucher (1972, 1978: part of the Kogelberg massif in the southwestern Cape; 1987: West Coast forelands), Van Rooyen (1978: northern Kruger National Park), Van der Meulen & Westfall (1979: bushveld of former western Transvaal region), Van Rooyen et al. (1981: northern Kruger National Park), Cowling (1982, 1984: Humansdorp region), Gertenbach (1983: Kruger National Park), Moll & Bossi (1983: Fynbos Biome and adjacent areas), Taylor (1984: southern Cape Peninsula), Rebelo et al. (1991: Riversdale Plain), Cowling & Heijnis (2001: southwestern Cape) and Vlok et al. (2003: planning region of STEP including Albany Thicket Biome and neighbouring areas).

There are two basic traits which set our Map apart from other comparable products:

1) Our Map is unique in featuring the vegetation cover of an extremely diverse large geographical region housing nine biomes on the continent and a further two biomes on the islands in great detail. The mapped regions contain the most species-rich temperate flora of the world. It includes one entire biogeographical plant kingdom (Capensis) and parts of phytochoria of two other plant kingdoms, namely of the Palaearctis and of Antarctis (sensu Takhtajan 1986).

2) Our Map, unlike other long-term projects featuring large regions (Europe, former Soviet Union, South America, USA), has been using fully computer-aided (GIS-assisted) tools from the onset of the research throughout the entire process up to publication. The use of aerial photography, satellite imagery, spatial predictive modelling and large databases in combination with traditional field-based ground-truthing is another distinct feature of our product.

4. The Making of VEGMAP

The current work was initiated by Prof. B.J. Huntley, Chief Executive Officer of the then National Botanical Institute (NBI), who convened a workshop at Kirstenbosch, Cape Town, on 7 and 8 August 1995. This was a national workshop of vegetation experts to discuss the feasibility of the project. The NBI commenced work and co-ordination on the project on 1 October 1995, with the official contractual commencement date of 30 January 1996. The administration of the funding and management of the project was an NBI (and later a SANBI) responsibility.

M. O'Callaghan was initially responsible for running the project, soon to be replaced by D.J. McDonald at the Kirstenbosch Research Centre of the NBI. At that stage M.C. Rutherford was the convenor of the project. Upon McDonald's resignation in July 2000, M.C. Rutherford was given direct responsibility for the project through to its completion. In the first year of this period the services of L. Mucina were engaged as scientific

co-ordinator and he continued informally in this role. He had also been contracted earlier (since February 2000) to deal with a number of specific issues relating to the project. From April 2003 M.C. Rutherford was placed on the project on a full-time basis, first attending to the completion of the map (the beta electronic version of the map was made publicly available in February 2004) and then joining L. Mucina in compiling some of the chapters and editing the book.

The period before 2000 was primarily one of promoting the buy-in of contributors (a major task at the time given many sensitivities about data-sharing) and assisting with computerisation of data. Various workshops on the project were convened (including ones on the use of TURBOVEG (Hennekens & Schaminée 2001) in February 1997 and October 1998) and the NBI co-ordinator visited many contributors and potential contributors. Numerous presentations on the project were made, the first by M. O'Callaghan at the Annual Congress of the South African Association of Botanists in Stellenbosch in January 1996. Various publications on the project appeared (McDonald 1996, 1997a, b, McDonald & Boucher 1999). A VEGMAP Co-ordination Committee functioned during the first phase of the project with representatives from the NBI, University of Pretoria, Stellenbosch University, the then University of Natal and the Agricultural Research Council in Grahamstown. An important workshop was held at the Kirstenbosch Research Centre on 30 September and 1 October 1999 where it was agreed that data encoding or acquisition for the project should cease by April 2000 and that the analysis and mapping be given a high priority immediately thereafter.

The very first parts of the map were received from some contributors in late 2001. However, many of the initial contributions had to be extensively revised or replaced.

Ultimately, well over 100 people from a wide range of organisations contributed to the map and/or the book (see Acknowledgements towards the end of this chapter). This was a large co-operative project. Even Acocks did not operate in isolation, working, for example, with Louis Irvine (see also Irvine 1941) from 1940 to 1942 while based in the current Limpopo Province. He also assisted Prof. J.M. Hector with an update of his vegetation map of South Africa which was never finished but formed the basis for Acocks' *Veld types of South Africa* (Hoffman & Cowling 2003a, b). Low & Rebelo (1996) list seven contributors to their work.

The current work maps 435 vegetation units in South Africa, Lesotho and Swaziland. This is over six times that of Acocks or Low & Rebelo. The number of individual polygons mapped is 32 times the number in Acocks and almost five times that in Low & Rebelo (Table 1.1). In addition, there are five vegetation units mapped on the Prince Edward Islands (part of South Africa) in the Southern Ocean. Altogether new at the subcontinental level in Africa is the mapping of azonal units, which was not possible at previous mapping scales even if there had been a determination to map these units. The printed map is at a larger scale (1:1 000 000) than any previous vegetation map for the region. Differences in level of detail are most dramatically shown in the Succulent Karoo Biome where Low & Rebelo (1996) recognised only four vegetation units compared to the 63 of the current work.

Table 1.1 Properties of the current vegetation map compared to two major maps published earlier.

Properties	Vegetation maps		
	Acocks (1953)	Low & Rebelo (1996)	Current work (2006)
Published scale	1:1 500 000	1:1 850 000 1:2 000 000 1:3 880 000	1:1 000 000
Vegetation types	70	68	435
Zonal vegetation types	70	68	401
Azonal vegetation types	0	0	34
Polygons	548	3 661	17 796
Average mapped unit area (km^2)	2 313	345	71

International comparisons include the 116 vegetation types of Küchler (1964) for the conterminous United States. The more recent mapping of Europe (about eight times the area of our mapping domain) resulted in many more (around 700) vegetation units (Bohn et al. 2003), but with number of polygons very similar to that of the current work.

5. Structure of the Book

This book is basically constructed as an explanatory account of the new Vegetation Map (Mucina et al. 2005, see also Chapter 18 of this book). The basic unit of the map is 'vegetation type'—these types are described in the forthcoming chapters and grouped either within a biome (in the case of zonal units) or otherwise convenient group (especially the azonal units and insular vegetation). Each vegetation type has a unique code which shows its higher rank classification. The descriptions of vegetation types follow a specific and consistent order. The heading gives the code and name of the specific vegetation unit, followed by the synonymy (mostly defined as a proportion of overlap with previously published mapping units), data on distribution, accounts of vegetation and landscape features, geology and soils, climate, lists of important taxa (including endemics) ordered according to growth form, followed by conservation information, remarks, and ending with literature references relevant to the vegetation unit. Most vegetation types are illustrated by colour photographs. Over 28 500 taxon entries (featuring about 10 000 different taxa) are listed in the descriptions. Four vegetation types are described but not mapped: two are in the marine environment and the remainder on the Prince Edward Islands. The methods and procedures that were followed are described in Chapter 2. The biomes and bioregions are briefly described and compared in Chapter 3; more extensive ecological accounts of the biomes or other groups of featured vegetation types appear in the introductory sections of each chapter. The biome chapters also aim to cover much of the ecological and biogeographical publications relevant to the biome, often with extensive literature lists. The azonal vegetation types are described after the biome chapters, followed by the chapter on the vegetation of the Prince Edward Islands. Just before the atlas section, are two chapters dealing with conservation issues relating to the vegetation types. In some places the mapping detail pushes the bounds of printing at a scale of 1:1 000 000. The electronic version on the CD inside the front cover of the book should be consulted where the user can zoom in at any scale to discern detail. There is a section on Credits at the end of each major chapter indicating specific contributions to the given chapter. The section on Acknowledgements below attempts to list all contributions and organisations that have played a role in the project.

6. *Quo vadis?*—Outlook and Expectations

The results of the VEGMAP Project as presented in this book represent a current account of our knowledge of the variability of the vegetation of this extremely variable, fascinating and

beautiful part of the world. Although it might, perhaps, constitute a milestone in vegetation science in South Africa, VEGMAP definitely is—above all—a process. The editors and the authors are well aware of loose ends, deficiencies and omissions that would have to be attended to in new editions of both the Map and the book. VEGMAP has, since being initiated as a nation-wide project, inspired new research in less known parts of this region and into poorly known segments of its vegetation cover. New data are being amassed which will shape new editions of our Map. The new knowledge will not only assist in filling the gaps but may also uncover new ones that require attention. The editors therefore encourage readers and users of our products to make us aware of their published and unpublished work and to point out any omissions, errors and deficiencies.

All our efforts would be in vain if our products did not find their way to the user. The map of veld types (1953 and subsequent two editions) by John Acocks served the academic community and the public as a major baseline study in vegetation classification for more than 50 years. The influence of his work was enormous (see the special issue of *South African Journal of Botany*; Hoffman & Cowling 2003a). Cowling (1999), using data of the Institute for Scientific Information, identified the Acocks' account of veld types as the most cited ecological text written in South Africa. It fills us with pride and satisfaction that even before the official release of the major products of VEGMAP (Mucina et al. 2005 and this book), the baseline data (the electronic shape-files of the Vegetation Map; Mucina & Rutherford 2004) have been used in several major scientific and conservation-planning undertakings. Among these rank the Millennium Assessment/Gariep Basin (Bohensky et al. 2004), Succulent Karoo Environmental Project (known as SKEP; Driver 2002, Driver et al. 2003), and last but not least, the *National Spatial Biodiversity Assessment 2004* (Driver et al. 2005; see also www.sanbi.org for a full report). We also notice that the new Map is used by conservation authorities, tertiary institutions as well as a large community of environmental consultants.

VEGMAP is a prime example of good descriptive vegetation science. Vegetation description, finding its expression in modern practically oriented vegetation surveys, should regain its function as a useful tool assisting in the unravelling of the secrets of vegetation. Ultimately, it is the descriptive vegetation science that produces baseline data and aids the formulation of hypotheses which should then undergo rigorous testing to lead us towards understanding the organisation and functioning of our vegetation.

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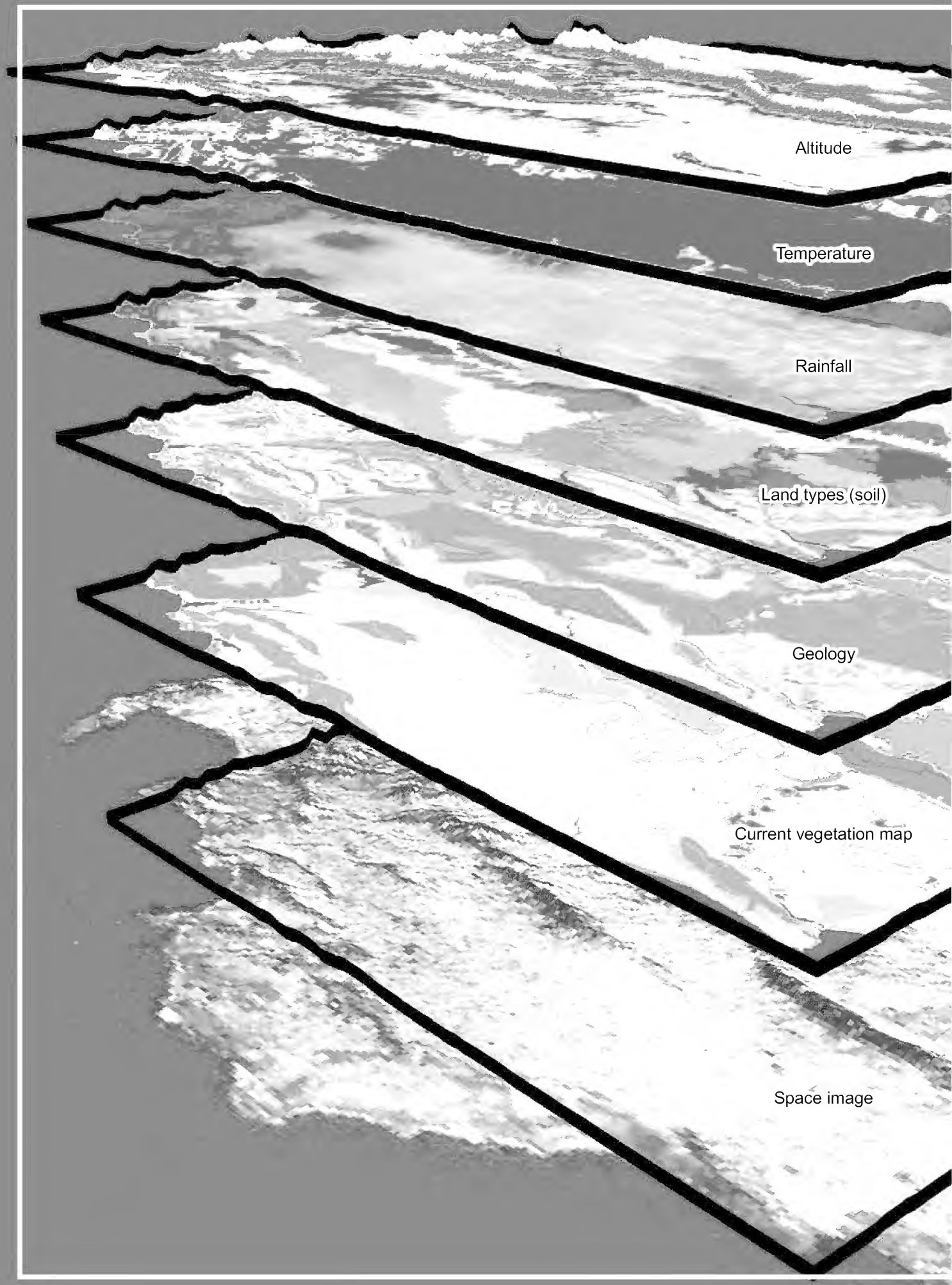
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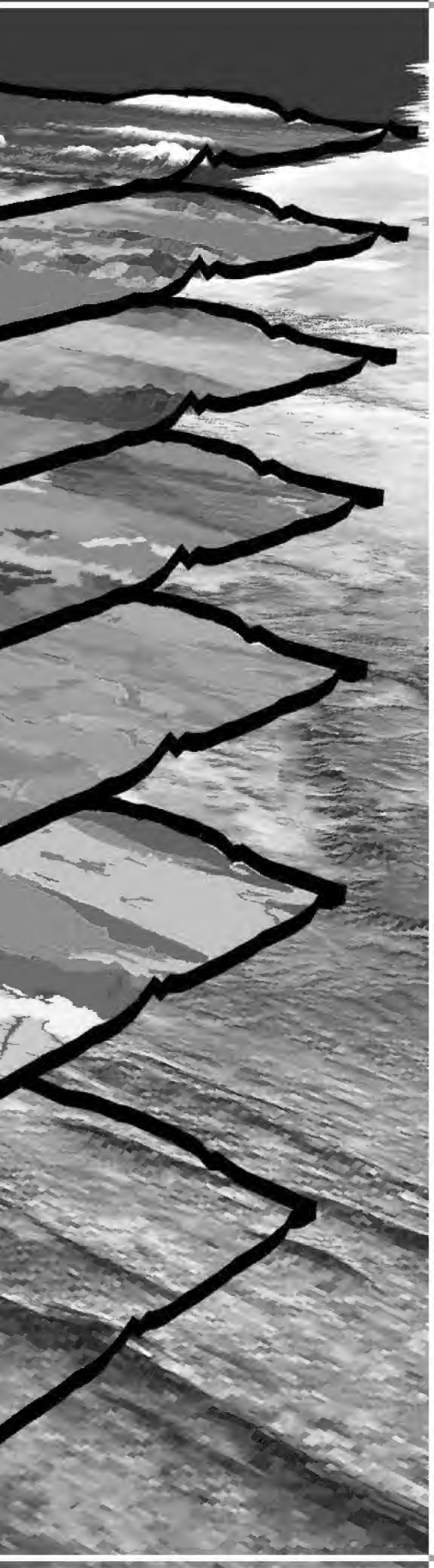
Temperature
Rainfall
Land types (soil)
Geology
Current vegetation map
Space image



The Logic of the Map: Approaches and Procedures

2

Ladislav Mucina, Michael C. Rutherford and Leslie W. Powrie

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Figure 1.1 Some of the data layers used to assist in drawing VEGMAP, the end product being the second layer from the bottom.

L.W. Powrie

1. Introduction

This chapter sets out the theoretical background and practical procedures adopted by the VEGMAP Project. We describe how we arrived at the two major products of our Project—the vegetation map of South Africa, Lesotho and Swaziland (Section 6) and the descriptive book (Section 7).

Mapping of vegetation of a region comprising 11 biomes, about 20 000 species (more than 24 000 taxa) of plants, experiencing a wide range of climates, from subtropical to polar, and spanning the oldest and youngest rocks on this planet, was a daunting task. The complexity of this task is clearly mirrored in the complexity of our approach and justifies the detail contained in this particular chapter.

This chapter starts with theoretical sections (1–4) in which we argue our case for the choice of the type of the map and for the basics of the mapping procedures. These are followed by a section (5) on sources of the data used in construction of our Map (as well as other mapping products such as the map of biomes and bioregions), and the Book. There are two methodological sections: Section 6 describes the technical details of the vegetation mapping and Section 7 explains in some detail the structure of the descriptions of vegetation units that form the core of the book.

2. Aims

The aim of the VEGMAP project was to produce a scientifically sound theoretical classification of the vegetation of South Africa, Lesotho and Swaziland, and to depict it as a vegetation map which:

- documents the diversity of the plant cover of southern Africa,
- reflects our current knowledge of the structure and biogeographical patterns of the vegetation of southern Africa,
- determines a baseline for land managers and others concerned with land and biodiversity (including agriculture, forestry, nature conservation, tourism etc.).

Vegetation mapping is a simplification and modelling exercise. We thus attempted to achieve two goals:

1) to produce a map featuring vegetation mapping units represented in simplified forms to create a *graphical spatial model* of vegetation of the region, and
2) to describe these vegetation mapping units using various floristic, vegetation, biogeographical, physico-geographical and environmental descriptors (Distribution, Vegetation and Landscape Features, Geology & Soils, Important Species, Endemic Species etc.)—to create a *verbal model* of the vegetation of the mapped region depicted in the book.

3. Basic Postulates of Vegetation Classification and Mapping

The entire exercise (all stages including preparation, execution and production of the Map) was based on the following postulates which form the basic theory of vegetation ecology:

Postulate 1: Vegetation is a real, tangible object expressed in the form of recognisable patches.

In other words: vegetation is a real phenomenon and can be studied.

Postulate 2: The differences between the vegetation patches in terms of structure, texture (floristic composition) as well as in terms of environmental composition of the habitats supporting the vegetation, make the classification of vegetation (or conceptualisation of theoretical constructs called 'vegetation types') possible.

In other words: we can classify vegetation patches into vegetation types.

Postulate 3: The great complexity of vegetation, both of a discrete and continuous nature, makes the classification of vegetation (or the reduction of information content to a simplified system) necessary.

In other words: classification is one (and a very effective) way of simplifying the complexity of vegetation.

Postulate 4: The levels of difference between vegetation types make building of a hierarchical system (comprising a series of nested vegetation types and their groups) possible. The hierarchical system is another tool for further simplification of vegetation complexity.

In other words: the hierarchical system is another effective way to view important emergent properties of the major patterns of vegetation.

Postulate 5: The structure and dynamics of vegetation is a result of properties of its constituent plant populations and their response to the nature and dynamics of the environment which can aid classification and mapping ('vegetation-environment axiom').

In other words: environmental conditions determine (together with the properties of vegetation itself) the complexity of vegetation.

Postulate 6: Vegetation is composed of populations of plant species (representing taxa). Each taxon often shows an individual response to ecological factors and hence serves as an important ecological indicator. Major efforts to devise an alternative classification of functional types have yet to yield a viable system for widespread application.

In other words: we use floristic composition as the primary entity for the conceptualisation of mapping units.

Postulate 7: Vegetation patches occur in space, hence they can be mapped in spatial models.

In other words: complexity of vegetation can be shown on a map.

4. Vegetation Map as a Model: a Conceptual Framework

A vegetation map is a spatial model construct. It is shaped by various scaling considerations, including both objective scaling elements (e.g. extent of the mapped area and its abiotic and biotic complexity), and subjective scaling elements—which are a result of our intellectual, technical and financial or otherwise socially motivated constraints (including availability and quality of data, power of the mapping techniques, funds available, time schedule, contractor's requirements, presentation limits and market demands).

4.1 Basic Concepts

Several crucial concepts dominate the methodology of vegetation mapping, the most important being *mapping theme* (type of map), *mapping scale* (detail captured and presented),

mapping element (basic mapping unit), and *unit hierarchy* (the way the mapping units form logical complexes). The latter two concepts relate directly to the *mapping legend*—a catalogue of mapping units often showing their classification as a hierarchical scheme.

4.1.1 Mapping Theme

Mapping vegetation means constructing a model which represents a particular idea about the complexity of vegetation. Hence, vegetation mapping is a modelling exercise aimed at presenting a hypothesis, at its best a hypothesis carrying a predictive message about vegetation patterns and dynamics. As there are many ways to perceive the phenomenon called 'vegetation', many types (themes) of vegetation maps can exist.

Large stretches of natural vegetation of South Africa, Lesotho and Swaziland have been turned into arable land, artificial plantations, towns and villages or have disappeared under the water of large dams. Still, owing to only very recent intensive agricultural activity (less than 350 years of the 'post-Van Riebeeckian period'—a very short time indeed when compared to thousands of years of large-scale agriculture in Europe), even larger stretches of land are blessed to still have a nearly natural vegetation cover. Nevertheless, we have refrained from applying the concept of 'real' (current) vegetation as the leading mapping theme because of the low feasibility of capturing the original character of the real vegetation at the mapping scales used in data collection and especially in presentation (see Section 6.3). In some cases the previous distribution of a vegetation type was simply unknown and only the extant distribution could be mapped. Most important here are forest patches where the heavy demand for timber over the last two to three centuries had very likely reduced areas of forest. Some highly fragmented units representing special habitats (such as SKk 8 Piketberg Quartz Succulent Shrubland, FRc 1 Swartland Silcrete Renosterveld and FRc 2 Rûens Silcrete Renosterveld) have probably been highly transformed prior to our current information on their distribution. Possibly the most extensively transformed areas are those termed 'coastal belts' (including CB 1 Maputaland Coastal Belt, CB 3 KwaZulu-Natal Coastal Belt, CB 5 Transkei Coastal Belt and AT 9 Albany Coastal Belt). Knowledge of the patterns and processes for reconstructing the vegetation in these regions through modelling is lacking. At least the extant forest patches have been mapped within these coastal belt units.

Most of the mapped area is close to the theme of 'potential natural vegetation' of Tüxen (1956, 1963, 1978). According to his approach (for more detail see also review papers by Kowarik 1987, Kalkhoven & Van den Werf 1988, Härdtle 1995 and applications as cited in these papers), the potential natural vegetation is defined as (according to Tüxen 1956 in Härdtle's 1995 translation): 'imagined natural state of vegetation … that could be outlined for the present time or for a certain earlier period, if human influence on vegetation was removed'. Using more current terminology and in simplified terms, Kowarik (1987) suggested that the 'present day potential natural vegetation is a hypothetical (potential) most developed vegetation, corresponding to present (not future) site conditions'. This definition serves especially well for vegetation of extensive southern African veld, especially farm land that has experienced changes through continuous and large-scale exploitation (including grazing by animals, brush-cutting and the like). The concept of 'veld resting' (excluding portions of farms from intensive exploitation for certain periods) is based on the experience of vegetation recovering into, if not an original, at least a more natural state when the human-controlled influence is removed. It is also highly probable that even ploughed land can return to a near natural state of vegetation (such as grassland) after abandonment (see for instance Smits et al. 1999). We acknowledge that the philosophy of a clear distinction between vegetation with humans and vegetation without humans is sometimes fanciful, especially in African savannas with their age-old association with human influence and 'disturbance', especially through the use of fire.

Our Map, however, also features 'reconstructed natural vegetation' (see Neuhäusl 1963, 1968, 1984 for more details). In regions that have experienced irreversible changes (such as in urban settlements through destruction of the natural soil cover as well as through drastic changes to local hydrology) the vegetation has been 'reconstructed' through modelling. In printed form, our Map either shows areas with reconstructed vegetation (under built-up urban areas, with the latter superimposed) to indicate the current extent to which this vegetation has been removed, or follows conventional cartographic practice to override vegetation of areas flooded by the water reservoir of a dam. However, the reconstructed vegetation below the reservoirs of dams can be viewed on the CD accompanying this book. This was needed for correct calculations of the proportion of vegetation transformed for the conservation sections of the book.

As a matter of reference, Acocks (1953, 1975, 1988) also employed the term 'potential' in his definition of 'veld type'. He then mapped his veld types in their 'potential' extent and not as patches of 'real' vegetation.

4.1.2 Mapping Scale

The size of the mapping realm (almost 1.3 million km^2) as well as the remarkable diversity of the flora (hence vegetation) supported by complex geological, climatic and hydrological patterns, proved challenging for mapping the vegetation. The decisions regarding the mapping scale(s) and the scale(s) of map presentation were dictated by our goals (see above) and these were modified by various serious constraints. Most compelling were: (a) the extent of the mapping area, (b) time and budget, (c) available expertise, (d) quality of data, and (e) technical level of mapping tools.

The scale of 1:250 000 was selected as the initial working scale, especially since many of the proxy data sets, such as geology, land types, topography (see Section 5 of this chapter for sources) were available in sufficient detail and precision at that scale. The consequent implementation of GIS technology, and local availability of more detailed sources (at 1:50 000, 1:10 000, etc.), allowed departure from the preliminary scale and facilitated increased detail of mapping where warranted, often resulting in greater refinement of the borders between vegetation units. Although such detail cannot be visible on our printed 1:1 000 000 maps, the electronic version (see CD) has no such limitation and a precision of down to 100 m (and even less in some cases) was possible where necessary.

The Prince Edward Islands were mapped at a working scale of about 1:25 000.

4.2 Vegetation Units, Mapping Units, Mosaics and Transitions

4.2.1 Definition of Vegetation Unit

At the scales of data collection (1:250 000 and sometimes more detailed) and presentation (1:1 000 000) our Map cannot show distribution of plant communities that operate on the habitat level. Our basic units of mapping, here called *vegetation units*

(e.g. FFs 11 Kogelberg Sandstone Fynbos, FOa 2 Swamp Forest and AZd 3 Cape Seashore Vegetation), are mostly identical to *mapping units*—those units shown on the map. (Examples where the mapping units are not identical with vegetation units are found in Chapter 15.) Using the general (and neutral) term 'mapping unit' we also designate the high-level units such as bioregions and biomes (see below and Chapter 3).

Vegetation Unit—the basic element of the Map—is defined as a *complex of plant communities ecologically and historically (both in spatial and temporal terms) occupying habitat complexes at the landscape scale.* Our vegetation units are the obvious vegetation complexes that share some general ecological properties such as position on major ecological gradients and nutrient levels, and appear similar in vegetation structure and especially in floristic composition.

The decisions to classify habitat-level communities into vegetation complexes forming the basis for definition of our landscape-level vegetation units, are governed by the following principles:

- close position along dominant ecological gradients

  Example: different estuary plant communities of flooded habitats (differing only in frequency of flooding).

- dominant ecological factor at landscape level

  Example: high salt content in soil selecting for a limited number of plant communities.

- dominant vegetation structure

  Example: fynbos shrublands on sandstone (often differing dramatically in floristic terms, but showing similar vegetation structural traits, especially growth form composition).

- high level of floristic similarity (including shared local and regional endemics)

  Example: various low shrublands in Succulent Karoo.

- close proximity

  Example: patches of distinct plant communities (that also satisfy a number of criteria listed above) in close proximity of one another can have a higher probability of shared elements and hence of being classified into the same vegetation unit than those more widely separated.

- potential

  Example: recovering vegetation of old fields classified as that of the surrounding grasslands.

It is obvious that not all these criteria could be used or would carry the same weight in delimitating our vegetation units. The order of importance or weighting of these criteria depends very much on the character of the vegetation (species-poor to species-rich, structurally simple to complex, clear versus fuzzy borders between patches) or character of ecological gradients shaping the vegetation landscapes within particular biomes (steep gradients versus shallow gradients, many ecologically functional factors versus few factors).

4.2.2 On 'Mosaics'

The concept of *mosaic* automatically implies at least two recognisable elements (in our case at least two vegetation units). The recognition of a mosaic can happen only *à posteriori* (after we have defined the elements). The term mosaic is used in mapping (not only vegetation mapping) to overcome the difficulties emanating from mapping scale. Examples are where local geology, local microclimatic and hydrological conditions, and natural disturbance factors (and various combinations of these) at detailed scales create a complex of clearly demarcated habitats supporting patches of distinct plant communities. In other words, where the grain of patchwork of habitats (supporting distinct vegetation units) encountered cannot translate onto a map of scale of choice, mosaics are often invoked as a concept and name. The patches of respective vegetation units simply become 'dissolved' into neighbouring vegetation units.

The decisions for not mapping mosaics onto a map are often due to lack of (field) mapping precision and lack of suitable small-scale data.

On our Map we have refrained from using the concept of mosaic in mapping the vegetation of continental South Africa, Lesotho and Swaziland for the following reasons: The field mapping scale we adopted (1:250 000) is so coarse that, if our vegetation units represent a landscape-level of complexity, we should almost always have had to disregard small patches of other vegetation units that are embedded. These small patches have indeed been mapped in regions where our data allowed us to work at a mapping scale of 1:50 000, and their coverage is available in electronic (GIS) format. However, these embedded patches had to be masked out ('dissolved') for the map presentation at a 1:1 000 000 scale to avoid creating 'salt-and-pepper patterns'. In fact, technically speaking, all patches of vegetation as represented on our Map at the scale of 1:1 000 000 (Mucina et al. 2005 or Chapter 18) are invariably mosaics! We admit that some of our vegetation units are of extreme mosaic nature—a reflection of the microscale spatial differentiation and often a lack of such precise data. Among the most prominent are the alluvial units (AZa; see also Chapter 13) which can comprise riparian thickets, flooded grasslands, reed beds and even patches of aquatic vegetation found in the streams and in alluvial backwaters.

Of the recent (though unpublished) maps, the one of the STEP region (Vlok & Euston-Brown 2002) uses the concept of 'mosaic' extensively.

The vegetation map of the Prince Edward Islands (see Chapter 15) is a notable exception in our handling of 'mosaics'. Here the intricate local topography and associated hydrology on the one hand and the influence of sea and animals on the other at low altitudes create small-grained mosaics of habitats impossible to depict at a mapping scale 1:25 000 (approximate field mapping scale), but the plant communities supported by these habitat mosaics are sufficiently distinct to qualify as vegetation units. However, since our current data do not allow clear delimitation of these distinct vegetation types as units, we have decided to present them on the map in the format of 'mosaic' mapping units. It is here where the concept of 'mapping unit' does not match the concept of 'vegetation unit'. The mapping unit termed 'Subantarctic Mire-Slope Vegetation' contains three vegetation units (ST 3 Subantarctic Mire, ST 4 Subantarctic Drainage Line and Spring Vegetation and ST 5 Subantarctic Fernbrake Vegetation), while the mapping unit termed 'Subantarctic Coastal Vegetation' comprises two vegetation types (ST 1 Subantarctic Coastal Vegetation and ST 2 Subantarctic Biotic Herbland and Grassland).

4.2.3 On 'Transitions'

Interestingly, exactly the same theoretical framework used to handle mosaics in vegetation mapping can be applied when so-called 'transitional' areas (regions) or ecotones are considered. While the term mosaic implies clearly (crisply) defined ingredi-

ents (elements), the term 'transition' entails gradual change between two (and rarely more) entities (for instance vegetation units). The concept of 'transition' in ecology has deep roots in the precept of the continuum in vegetation ecology (the current reigning paradigm). However, the controversy between continual versus discrete variation in vegetation is surely a matter of scale (see the seminal theoretical paper by Austin & Smith 1989 on the matter).

We acknowledge that the borders between some units, especially those where the controlling ecological factors change in a continual manner (for instance climatic factors in areas of uniform topography), are arbitrary and imply a midpoint in the transitional zone. These include the units straddling the border regions of some biomes (defined by climatic factors in the first place), including NKl 1 Gamka Karoo and SKv 6 Koedoesberge-Moordenaars Karoo, NKu 4 Eastern Upper Karoo and Gh 3 Xhariep Karroid Grassland, SKt 3 Roggeveld Karoo and NKu 1 Western Upper Karoo and a few others. There are also examples of some sharp transitions between biomes in places (see Chapter 3).

4.3 Hierarchy of Mapping Units

Following the theoretical principles of zonality of vegetation (discussed in detail in Chapter 13), we have separated the zonal and azonal vegetation units. For practical reasons we maintain all indigenous forest units within one informal group, although they represent a mixture of units belonging to two forest biomes (Afrotemperate Forest Biome and Subtropical Coastal Forest Biome or Indian Ocean Coastal Belt) and azonal forest units (riverine, swamp and mangrove). More information about the azonal versus zonal status of the forests is presented in Table 12.1.

The azonal vegetation units are grouped (for purposes of structuring the legend and the descriptions) in a similar way. Here the ecological (groups of azonal units according to dominant character of hydrology or salt content) and (phyto)geographical (according to embedding within biomes especially) ones prevail.

With most of the remaining vegetation, our Map features a three-level nested hierarchy of the mapping units, namely the levels of (a) vegetation units, (b) bioregions (composed of vegetation units), and (c) biomes (comprising bioregions). To paraphrase the definition of 'bioregion' from Chapter 3: each bioregion is a composite of spatial (vegetation) units sharing similar biotic and physico-geographical features and connected by processes operating on a regional scale. Bioregions and biomes are discussed in Chapter 3.

5. Data Sources and Processing

Data included with the Map (Mucina et al. 2005) and used in the mapping and analysis processes were obtained from (or modified from data supplied mostly by) a number of organisations. Some features were edited and adjustments applied using the rubbersheet method to align the topographic data to scanned 1:50 000 or 1:250 000 maps, and to align the vegetation map and topographic data as required.

Not all data were available at the commencement of the project, and the development of the project may have been somewhat different had they been available at the outset of the project. Data that became available later in the project include topographic data from the Chief Directorate: Surveys and Mapping (CDSM), land types included with the Environmental Potential Atlas (ENPAT) from the Department of Environmental Affairs and Tourism (DEAT), and data on protected areas. Some data became available too late to have been used or included in the map or report.

Details of individual data contributions by authors are given in the Credits section of the chapter describing the relevant biome or other groups of vegetation units (forests, azonal vegetation or vegetation of the subantarctic islands).

5.1 Topography

The 100 m and 20 m contours and the scanned topographic maps were obtained from CDSM. The 200 m Digital Elevation Model (DEM) (Schulze 1997) was used to model some slopes in the process of mapping some vegetation types associated with slopes. Terrain morphology was consulted for describing some vegetation types (Schulze 1997). Some contour heights had to be corrected. Altitude profiles of vegetation types were derived as follows: The DEM was classified into 20 m classes and the class grid converted to polygons. These polygons were then combined with the vegetation map to obtain the intersection of vegetation types with altitude classes. The area of each polygon was then calculated and a single table created with vegetation type, altitude class, and sum of area. Frequencies of altitude classes in each vegetation type were then prepared as histograms which were used for describing the altitude profiles.

Other topographic data were obtained from the Chief Directorate: Surveys and Mapping (national Department of Land Affairs), Mowbray, Cape Town (w3sli.wcape.gov.za), reproduced under Government Printer's Copyright Authority No. 11243 dated 4 January 2005.

5.2 Geology, Soils and Land Types

Digital geological data obtained from the Council for Geoscience included the 1:1 000 000 map, 1:250 000 geology map for selected map sheets limited to the Fynbos Biome area, and the volcanology of Marion and Prince Edward Islands. Soils (Land Types) were obtained from ENPAT. Landsat (contrast-adjusted colour composite of TM bands 7,4,2 as R,G,B) satellite imagery was obtained from NASA. Predicted Soil Loss (erosion) data were supplied by the national Department of Agriculture (NDA).

5.3 Climate

Climate data were obtained from the *South African Atlas of Agrohydrology and Climatology* (see Schulze 1997). Selected temperature maxima and minima were extracted from data for climate stations of the South African Weather Service (SAWeather).

The climate diagrams (Figure 2.2) were prepared by summarising vegetation type zones (using ArcView 3) using the vegetation polygon theme and climate grids. For these diagrams, mean values were taken for each month for the Median Monthly Rainfall, Maximum Temperature and Minimum Temperature. Mean values for Mean Annual Precipitation (MAP), Annual Precipitation Co-efficient of Variation, Mean Annual Temperature, Mean Frost Days (days when screen temperature was below 0°C), Mean Annual Potential Evaporation and Mean Annual Soil Moisture Stress Days (percentage of days when evaporative demand was more than double the soil moisture supply) were taken to give figures for the parameters to the right of each graph.

Vegetation types with small portions in a given grid cell would not be represented in that cell in this summarising process. This resulted in statistics being biased towards parts with larger

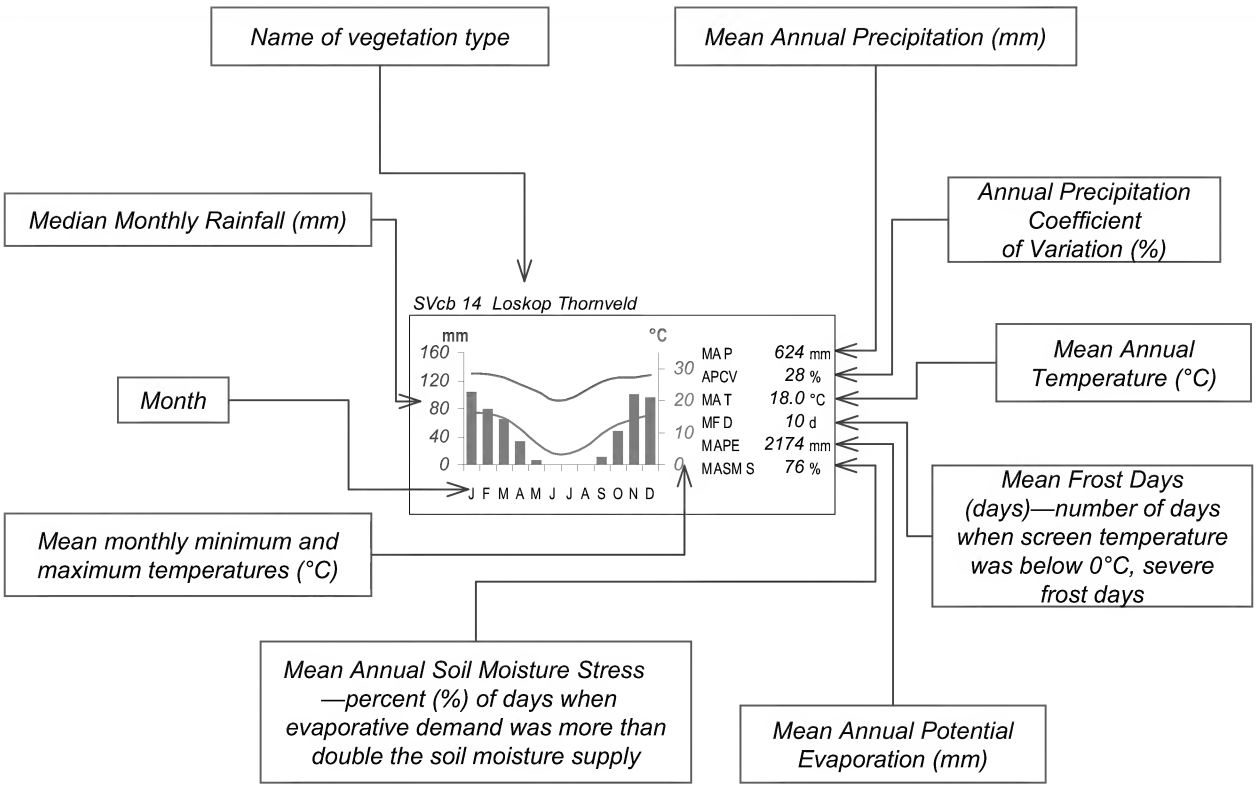

Figure 2.2 Example of a climate diagram with explanation of the elements.

extents of each vegetation type. This has particular relevance for shale bands, koppie units, etc. For example, it is likely that shale bands cross many grid cells but will have no data for many of those grid cells because they are not the majority of the total vegetation in those cells. Thus, for example, the shale bands might have skewed seasonality or other mean climate data over their ranges. Where there is no value for a type in any particular grid cell, each climate grid will have no data for that vegetation type in that grid cell, so in the same cell the data would be absent for each parameter. In some instances, i.e. SVcb 22 VhaVenda Miombo, AZf 2 Cape Vernal Pools and Dn 2 Namib Lichen Fields, each polygon was a minority in its respective grid cell and points were used instead of polygons to derive climate diagrams for these small units. Climate diagrams were not created for the Desert Biome and the Succulent Karoo units of the Richtersveld due to a lack of confidence in the modelled data in that area. In some of these cases, data for weather stations situated in the respective vegetation type were used to create modified climate diagrams.

Crosswalks were used for preparing some descriptions of vegetation types in Sections 7.2, 7.5, 7.6, 7.8. These crosswalks were derived by converting the climate grids to polygons and then overlaying the polygons and getting actual areas of overlap (in ha) of vegetation and each value for the climate. The crosswalks were done with classes of cell values (e.g. 1–10 mm of rainfall).

5.4 Sources of Plant Distribution Data

The main source of plant distribution data was PRECIS (National Herbarium [***PRE***] **C**omputerized **I**nformation **S**ystem)—a database managed from the Pretoria centre of the South African National Biodiversity Institute (Magill et al. 1983, Germishuizen & Meyer 2003). The spatial resolution of specimens in Specimen-PRECIS (about 800 000 records) is generally 1:50 000 map sheets, the so-called 'quarter degree squares' (QDS) (approximately 30 x 30 km). Because of this very coarse scale, the data were considered to be potentially useful only where a QDS was at least 90% within a vegetation type. An intersection of QDS with vegetation types enabled the calculation of the percentage representation of a grid cell in a vegetation type. Azonal types and sea within a QDS were taken into account, reducing the total area of the grid cell to be apportioned to the vegetation type. By referring to the individual collectors' label data, the accuracy could sometimes be greatly improved from incorrect or even missing geographical co-ordinates in PRECIS. In cases of outliers where the geographical co-ordinates and the locality description recorded by the collector on the label disagreed, we used the label data and not the geographical co-ordinates. Place names mentioned on specimens were checked against PRECIS Gazetteer, CDSM Gazetteer, ENPAT2001 (DEAT) cadastral data (farm names), and names of places and parent farms from SAExplorer (MDB). Data were generally used with greater confidence if the point was located within the vegetation type where the collecting locality was recorded by the collector with a precision of less than 2 km, as is the case with some older specimens, and increasingly so for newer specimens where GPS is used.

The ACKDAT database (O'Callaghan 2000) is curated at the Kirstenbosch centre of the South African National Biodiversity Institute and contains about 300 000 records of data on species presence and abundance and sometimes habitat. It was created by the computerisation of J.P.H. Acocks's field notes (Rutherford et al. 2003) recorded during some 44 years of field work throughout South Africa and parts of Swaziland. Geographical co-ordinates generally have a precision of about 1.5 km. We

used ACKDAT data for sites specifically selected as being representative of the vegetation type in which each occurred. For example, if sites were close to the edge of a type or if Acocks's description of the site indicated that it was not typical of the vegetation type, the data were generally not used for that type if better alternatives were available. Acocks sometimes specified the habitat of a site as forest or pan, making it unrepresentative of the surrounding type being described. Because of the progress South African taxonomy has made over the past 50 years, many of Acocks's records considered as useful were checked against other sources for identification certainty. In the process, for instance, all records for vygies (Aizoaceae) were disregarded. The Nama-Karoo sites of Acocks served as a basis in preliminary steps towards mapping of the biome (see Section 6.2.2 further on).

The third important source of distribution data was the database of the Protea Atlas Project (Rebelo 1991). It currently contains about 265 000 high-precision records of all Proteaceae occurring in southern Africa, collected by professionals and trained amateurs. Data usually include an estimate of abundance and sometimes habitat. The database is curated at the Kirstenbosch centre of the South African National Biodiversity Institute and served as a major source of data, especially for the descriptions of the vegetation units of the Fynbos Biome.

National Vegetation Database (Mucina et al. 2000) served as a source of vegetation data in some preliminary classification studies in several fynbos regions as well as for classification of the forest data (Von Maltitz et al. 2003, Mucina & Geldenhuys 2002, Geldenhuys & Mucina 2006), the results of which led to the definition of the forest vegetation units in our Map. The vegetation data are stored in the form of relevés (list of taxa per plot) and are managed by the TURBOVEG 2.0 software (Hennekens & Schaminée 2001). This database was used as a source of plant species distributions in relatively few cases because of the frequent lack of geo-referencing of sampling plots.

Gertenbach's (1983) species lists for landscape types in the Kruger National Park were a useful source of species data which helped to shape the species lists of all vegetation units of the Park.

The distribution of alien plant species were sourced from the National Invasive Alien Plant Database (CSIR) (McKelly et al. 2000).

The species lists of the descriptions of vegetation units extracted from the databases listed above were further supplemented by:

- distribution data from all major taxonomic revisions and monographs of southern African genera,
- all major flora field guides featuring various segments of the flora of the region,
- unpublished (and not yet digitised) voucher collections from major herbaria in the region,
- unpublished records collected by many field botanists, both professionals and amateurs (see the sections on Credits in particular chapters as well as general Acknowledgements in Chapter 1).

5.5 Conservation Data

Protected areas network data were compiled in April 2005 for purposes of the National Spatial Biodiversity Assessment (Driver et al. 2005). They are included with the digital data of the Map and were also used for describing the proportion of most vegetation types statutorily conserved. These included national parks from the SANParks, and other data collected for the National Spatial Biodiversity Assessment. SANParks supplied some recent changes and missing data, such as those on the proposed Garden Route National Park. Some conservation areas were digitised from sources at SANBI and SANParks, e.g. Tšehlanyane National Park in Lesotho. See above for the source of the alien plant coverage.

Census data (from SAExplorer from the Municipal Demarcation Board) were consulted in some cases to help locate areas of major human pressures in some vegetation types.

See also Section 5.7 for man-made impacts.

5.6 Other Vegetation Maps as Sources

Vegetation maps used as sources are referred to at their application in Sections 6 and 7. Gertenbach (1983) boundaries were used for our vegetation boundaries within the Kruger National Park.

5.7 Man-made Geographical Features

The basic cartographic data on political boundaries, settlements, roads and dams were conventionally applied, but with numerous necessary modifications to source data.

National and international boundaries were obtained from ENPAT, and borders with countries neighbouring the mapped area were corrected using 1:50 000 map images from CDSM.

Settlements (ranging from selected small groups of huts to cities) data from GlobalMap (supplied by CDSM) were used. Place names were updated according to gazetted names listed on the website of the South African Geographical Names Council on 1 January 2005. Names of some additional built-up areas were taken from data provided by CDSM.

Roads data were obtained from the Council for GeoScience. Some new roads were added, e.g. the stretch of N1 between Polokwane and Mokopane, the road north of Upington to Askam, some roads in the Richtersveld, Namaqualand, Maputaland and in Limpopo Province. The mapping of the road networks in Lesotho and Swaziland was improved. Railway data from GlobalMap were used, with some editing in Swaziland. Data on rivers were obtained from the Council for GeoScience. River courses were reconciled with the position of riverine vegetation and dams. They were checked against CDSM-scanned maps in certain instances.

A coverage representing radically altered landscapes was prepared using the classes 'Forest Plantations', 'Cultivated Lands', 'Urban/Built-up Lands' and 'Mines and Quarries' from the National Land Cover database (Fairbanks et al. 2000). CDSM 1:500 000 roads (excluding footpaths) were buffered (30 m for major roads, 20 m and up to 10 m for lesser roads) using GIS and added to the radically altered layer. Areas transformed by water impoundment were obtained from CDSM. Data on dams were derived mostly from 1:500 000 digital map data and some from 1:50 000 digital data, or by checking against 1:250 000 scanned maps, and some digitised using Landsat 5 images. Dams smaller than 100 ha (making up 3.6% of the total dam area) were omitted to avoid the many farm dams. Vegetation on islands of smaller than 20 ha in dams was not mapped. Dam names were checked against the dams shapefile from DWAF, scanned 1:50 000 and 1:250 000 maps, and independent sources. Certain dams that had not been in the dataset, were digitised, e.g. the Mohale and Marico Dams, and the coverage of some had to be corrected (e.g. Straussfontein Dam, Free State).

6. Vegetation Map as a Graphical Spatial Model

6.1 Mapping Procedures: Basic Features

In this section we shall address only the theory of the mapping procedures. The technical details of the mapping are presented in Section 6.2.

The mapping procedures adopted in the VEGMAP project include the following five basic features:

(1) Zonality concept as a major classification criterion.

(2) Recognition of controlling factors at the scale of mapping.

(3) Adoption of proxy data as major source.

(4) Application of a top-down approach in conceptualising mapping units.

(5) Bottom-up approach in building a hierarchy of mapping units.

Zonality. The enormous extent of the mapping realm (almost 1.3 million km^2) corresponds to the scale of the macroclimate which probably plays a major role in differentiating vegetation complexes at the subcontinental scale. The concept of zonality (Walter 1964) has been used as an *a priori* criterion in recognising azonal vegetation types under strong control of factors other than climate. The concept of zonality and related terminology is discussed at length in Chapter 13. Application of this prime criterion in our Map is unique in the history of South African vegetation mapping.

Controlling Factors. Vegetation patterns are a result of a complex of environmental factors co-acting both spatially and temporally. Various ecological factors determine the patterning and dynamics of vegetation and it is therefore essential to identify those most important to understand the distribution of vegetation types in space and time. Application of zonality (identifying those controlling climatic factors in zonal vegetation) was one of these essential steps. We consider those factors that control, for example, the diversity of the azonal (water dynamics, salinity) or zonal vegetation (soil patterns, geology).

Proxy Data. Because of the lack of primary vegetation data (including vegetation samples, interpretable remote-sensing coverage etc.) in many areas, vegetation mapping is forced to use proxy data—soil maps, geological maps, modelled climatic surfaces etc. The proxy data were extensively used in our mapping studies to create physico-geographical units to serve as a basis for recognition of vegetation units.

Top-down Approach. We used this approach in spatial delimitation and conceptualisation of the mapping units. Starting from broad mapping realms representing biomes (or other groups of plant communities) and applying the knowledge of the controlling factors, and aided by proxy data, we proceeded in subdividing the mapping realm into smaller homogeneous (physico-geographical) units. These units were then re-evaluated in terms of vegetation concepts, in other words the physico-geographical unit was characterised in terms of its vegetation cover and composition. Three basic steps constitute the process from the recognition of mapping units to their actual spatial mapping. These are: (1) spatial delimitation of units, followed by (2) conceptualisation (including calibration and verification) of the units, and finally (3) description by which the properties of the established mapping units are expressed in a comprehensive yet condensed text form to accompany the map and aid its interpretation. The last step is handled in more detail in Section 7 of this chapter.

Bottom-up Approach. Using the similarity in terms of vegetation structure and floristic composition as well as several other mainly ecological or physico-geographical traits, the distinguished vegetation (mapping) types were grouped into a nested hierarchy. In our terminology, the *vegetation units* (basic level) group into *bioregions* and these group into *biomes* (see also Section 4.3 in this chapter).

6.2 Mapping Procedures: Practical Approach

6.2.1 General Mapping Procedures

Commencing with the top-down approach, we handled the mapping of the target region (South Africa, Lesotho and Swaziland) in stages.

Stage 1: Initially we divided the target region into areas to be covered by particular mapping teams using the methodology as indicated in Sections 4.1 and 6.1 and adapted to local conditions (complexity of vegetation, extent of the area, availability of proxy and field data etc.). These areas were (1) Grassland and Savanna Biomes (excluding the Eastern Cape and KwaZulu-Natal), (2) so-called arid biomes, including Nama-Karoo, Succulent Karoo and Desert, (3) Fynbos Biome, (4) Eastern Cape and (5) KwaZulu-Natal. The Eastern Cape team mapped, among other vegetation types, also the southernmost extensions of Grassland and Savanna. Each of these teams (with exception of the arid biomes team) produced a map of the respective areas. The Grassland/Savanna team did not only create a new product for most of the area but relied heavily on existing (although not comprehensively published) maps covering the Kalahari region. The arid biomes were mapped, at this stage, in a different manner: the Nama-Karoo region (with broad buffer zone encroaching into neighbouring biomes such as Savanna/Kalahari, parts of Succulent Karoo and Fynbos and especially summer-rainfall parts of the Desert Biome) was mapped as an entity. The Richtersveld was covered by very detailed, unpublished survey data and the Namaqualand region (excluding the Richtersveld) was initially mapped using satellite imagery (see below for the details of the mapping procedures). The remainder of the target area (the Succulent Karoo area outside the above-mentioned areas) was mapped *de novo*.

The various contributors had been asked to map data and to digitise these and supply ArcView shapefiles in Decimal Degrees, WGS84 spheroid and Hartebeesthoek datum. Those mapping coverages supplied in Cape Datum, Clarke 1884 spheroid, or in mixed datum were reprojected. In cases where the supplied data were more inaccurate than could be attributed to the datum point (1.6 km northeast in the Molopo River area), the spatial adjust method of ArcGIS 8 using a rubbersheet of all features was used to adjust such portions of the map to align them to 1:50 000 data supplied by the CDSM.

Stage 2: This stage proved to be the most complex part of the whole process. After initial screening of the supplied products, we attempted the first stitching of the partial products to identify gaps and incompatibility of units along 'stitched' borders. During this period, new mapping sources, especially valuable unpublished maps, became available. Involvement of new collaborators who were asked to deal with local/regional mapping issues, led to a considerable revision of large portions of the initial mapping products supplied, especially in the Grassland, Savanna and Fynbos Biomes as well as in the Eastern Cape Province, Lesotho and Swaziland. A fresh attempt was made to map the vegetation of Lesotho and an unpublished map of Swaziland was supplied to the VEGMAP team at that stage. Both maps replaced existing initial mapping coverages of the

Grassland and Savanna Biomes within the borders of these two countries. A large part of the Fynbos Biome was mapped in a second attempt assisted by better digital (more detailed geological map) and floristic (improved access to extensive databases) data. The western portion of the initial Eastern Cape mapping coverage was replaced by the very detailed STEP map, which had to be simplified for the purpose of our Map and the limitations imposed by the mapping scales. The original KwaZulu-Natal map also underwent simplification and adjustments resulting from input from experts of Ezemvelo KZN Wildlife (especially in Maputaland, northern KwaZulu-Natal and in the Midlands). At this stage the very detailed Richtersveld map had also been adapted to our aims (simplified and improved in some boundary detail) in the first place and collated to fit the concepts of the neighbouring regions, especially the Namaqualand and northern Bushmanland coverage (originally part of the initial Nama-Karoo map). In summary, this stage saw (1) much improvement in providing more soundly based types and more accurately mapped units in local and regional coverages (through improved access to unpublished mapping sources and powerful proxy data as well as floristic databases), and (2) the 'stitching' process—a phase of reconciliation of different sources in spatial (boundaries) and conceptual terms involving unification of concepts of units subject to stitching.

In practice this meant many iterations operating at very different cycle lengths which, together with the number of vegetation polygons ultimately exceeding 17 000, required close and careful management. Numerous field checks and consultations were undertaken by the VEGMAP management team to improve the quality of the map.

Stage 3: Although less complicated than the previous one, this was a stage of small-scale improvement, including incorporation of comments of consulted experts, refinement of borders (increasing detail of boundaries at more detailed scale), handling of very small polygons for cartographic reasons and, finally, cleaning of the coverage.

Editing was done using ArcView 3.2. Occasional cleaning was done by converting the shapefile to an ArcInfo coverage using the ArcCatalog process to export the shapefile to coverage to generate topology for overlaps and gaps in the combined source data. Slivers resulting from overlaps between various coverages were identified and removed. Almost all polygons smaller than 5 ha were merged to the appropriate adjacent type to avoid a salt-and-pepper effect in the graphical presentation (too fragmented coverage consisting of many spatially separated polygons obstructing the general pattern).

6.2.2 *Specific Mapping Examples*

Grassland and Savanna

Most of the borders between the Grassland units of the Highveld north and west of Lesotho and much of the eastern Highveld and the Eastern Cape are frequently very similar to land type boundaries. Certain localised units west of Lesotho were mapped independently of land types, e.g. Gh 7 Winburg Grassy Shrubland, Gh 8 Bloemfontein Karroid Shrubland and Gm 7 Northern Free State Shrubland. Vegetation in KwaZulu-Natal has a somewhat lesser correlation with land type boundaries. Northern summit and eastern escarpment units of Grassland (e.g. Gm 20, 23, 27 and 29) as well as Lesotho and Swaziland do not follow land types.

Few vegetation units of the Savanna Biome follow land type boundaries. Those that do are mainly the Savanna Thornveld types of the Central Bushveld (units SVcb 1, 3, 6, 14 and 15) and the separation of SVmp 1 Musina Mopane Bushveld and SVmp 2 Limpopo Ridge Bushveld. Elsewhere there are some units that partially coincide with land type boundaries, such as the northeastern parts of SVl 3 Granite Lowveld, the western edge of SVl 1 Makuleke Sandy Bushveld, part of the eastern side of SVcb 21 Soutpansberg Mountain Bushveld, the southern edge of SVkd 1 Gordonia Duneveld and the northern parts of SVk 4 Kimberley Thornveld.

We also made use of boundaries of previously mapped vegetation types in the delimitation of some Grassland and Savanna units, for instance the landscape types of the Kruger National Park (Gertenbach 1983), units mapped in the Blouberg (Scholes 1979) and those of the Kalahari duneveld (Lubbinge 1998) etc.

While the Sub-Escarpment Grassland and Savanna units in the Eastern Cape (central to eastern regions of the province; D.B. Hoare & A.R. Palmer, unpublished data) were mapped using satellite imagery, the Sub-Escarpment units of KwaZulu-Natal in principle followed the borders of Broad Resources Groups (BRG) and Bioresource Units (BRU) as defined by Camp (2001 and the preceding series of reports). A BRG is defined as 'a specific vegetation type controlled by an interplay of biotic factors such as soil and altitude'. It is formed by one or more Bioresource Units, each of the same vegetation type, and related to one another in terms of climate and broad soil association patterns (Camp 2001). In the same work Camp defined a BRU as '… an area within which the environmental factors such as climate (rainfall, temperature and evaporation), soil type, vegetation and terrain type, have a degree of homogeneity such that land use practices, farming enterprises, production and production techniques, can be clearly defined for practical planning purposes'. Details on the mapping procedures leading to the BRG/BRU classification of KwaZulu-Natal are also given in Camp (2001).

Geology was used as a guide for boundaries of some Grassland and Savanna types, including units such as Gd 7 and 8, Gh 11 and 15, Gm 10, 22, 23 and 26, Gs 2, SVl 5, 6 and 13, SVcb 2, 7, 11, 13, 25, SVmp 4 and 8.

Altitudinal limits were used to approximate boundaries of, for example, Gm 20 Leolo Summit Sourveld, Gm 29 Waterberg-Magaliesberg Summit Sourveld, Gd 10 Drakensberg Afroalpine Heathland and SVl 17 Lebombo Summit Sourveld. Digital Elevation Model (DEM) data were used to calculate minimum slopes to identify some units associated with koppies, for example, Gm 5 Basotho Montane Shrubland and Gh 4 Besemkaree Koppies Shrubland. Topographic maps were used to identify units such as SVl 7 Gravelotte Rocky Bushveld, eastern outliers of SVl 9 Legogote Sour Bushveld and SVl 12 Kaalrug Mountain Bushveld. Gm 2 Senqu Montane Shrubland was mapped on the basis of steep slopes up to a maximum altitude approximating the upper limits of the sandstone. Much of the extent of the units where we applied DEM data extensively were later verified by ground truthing.

The approximate 600 mm isoline for MAP was used as an upper limit for Gh 2 Aliwal North Dry Grassland and for separating Gh 4 Besemkaree Koppies Shrubland on the dry side from Gm 5 Basotho Montane Shrubland.

Albany Thicket

The core (solid) thicket vegetation types of the Subtropical Thicket Ecosystem Planning (STEP) Project were closely followed for our Albany Thicket vegetation types. The mosaic thicket units of STEP were assigned as follows: The Fynbos units identified by the Fynbos mapping team took preference, and the remainder of the mosaics were then individually evaluated against avail-

able environmental evidence and either rejected, accepted or many were only partially accepted as a Thicket type.

Below we give various contrasting examples of our approach to assigning these mosaic units, or parts thereof, to vegetation types. Mons Ruber Fynbos Thicket (a STEP unit) was partly accepted as Thicket, with the rest going to the Fynbos Biome. Examples of mosaic types that were assigned in their entirety to the Fynbos Biome include Andrieskraal Fynbos Thicket, Kouga Fynbos Thicket and Alicedale Fynbos Thicket. A three-way split was applied to De Rust Karroid Thicket between AT 2 Gamka Thicket, Succulent Karoo and Fynbos.

In general, the gwarrieveld mosaic units were not assigned to the Albany Thicket, but rather to the Succulent Karoo or Nama-Karoo Biomes. Most of the area of the STEP 'doringveld units' were re-assigned as the azonal alluvial vegetation types.

All of Oudtshoorn Karroid Thicket, Kleinpoort Karroid Thicket and Koedoeskloof Karroid Thicket were accepted as parts of AT 2 Gamka Thicket, AT 3 Groot Thicket and AT 6 Sundays Thicket, respectively. However, all of Beervlei Karroid Thicket and Blossoms Karroid Thicket were assigned to NKl 1 Gamka Karoo and SKv 11 Eastern Little Karoo, respectively.

All of Albany Bontveld and Mountvale Grassland Thicket were assigned to SVs 7 Bhisho Thornveld, and Bedford Savanna Thicket was assigned to mainly Gs 18 Bedford Dry Grassland and SVs 7 Bhisho Thornveld. By contrast, Montcoke Grassland Thicket was all assigned to AT 12 Buffels Thicket. Umtiza Forest Thicket was split between AT 12 Buffels Thicket and FOz 5 Scarp Forest.

Arid Biomes

A multivariate data analysis of the link between the vegetation data (Acocks's species lists) and a set of environmental data harvested from GIS layers in the same localities (B. van der Merwe & W. Lloyd, unpublished data) revealed the controlling importance of environmental characteristics used for definition of land types (see Fairbanks et al. 2000). Therefore almost all the borders of the vegetation types of the large-scale Nama-Karoo units follow those of the land types. In the Richtersveld, mainly floristic surveys, topography and satellite imagery were used to help delineate the vegetation units. This also applied to the Desert units, except in the east and southeast where the MAP of 70 mm approximated the boundary between Dg 9 Eastern Gariep Plains Desert and Dg 10 Eastern Gariep Rocky Desert of the Desert Biome, and NKb 3 Bushmanland Arid Grassland and NKb 4 Bushmanland Sandy Grassland of the Nama-Karoo Biome.

Most of the area of Namaqualand (including Hardeveld, Sandveld and Knersvlakte) was mapped using a supervised-classification approach in interpretation of satellite imagery. Boundaries were improved by ground-truthing in many key regions of Namaqualand. In some of the high-altitude regions of Namaqualand the vegetation types (SKn 6 Kamiesberg Mountains Shrubland, FRg 1 Namaqualand Granite Renosterveld and FFg 1 Kamiesberg Granite Fynbos) we applied a combination of altitude and aspect in modelling the potential occurrence of the units. The vegetation types in the Little Karoo were either based on existing available mapping sources (such as STEP) or we used land types and additional field evidence. Quartz patches of the Little Karoo were mapped using expert field data. SKv 2 Swartruggens Quartzite Karoo was mapped using a combination of quartzite geology and low altitudes.

The extent of the gwarrieveld units (SKv 9 Western Gwarrieveld, SKv 12 Willowmore Gwarrieveld and NKl 3 Lower Karoo Gwarrieveld) in principle followed the STEP mapping coverage.

Fynbos Biome

Initial attempts to use the 1998 Landsat images proved unsuccessful, primarily because veld age was an overriding signature in the images. In addition, it was not clear whether the strong north-south slope dichotomy reflected true vegetation type differences or merely different insolation signatures. However, it was apparent that many of the patterns seemed to reflect geology, and therefore the imaging approach was largely discarded. One major unit carried over from the Landsat images, however, was the dichotomy between Olifants River Sandstone Fynbos and Cederberg Sandstone Fynbos, which differ markedly in the images, separating at the scarp water catchment boundary. It also influenced, together with floristic and structural data for the Langeberg and Swartberg, the separation of the east-west fold mountains into units limited to north-facing and south-facing aspects respectively, rather than regarding each range as a single entity. An electronic version of Moll & Bossi (1984) at 1:250 000 scale, used by Low & Rebelo (1996) was considered too coarse for the delineation, as were Cowling's Broad Habitat Units (Cowling et al. 1999). Consequently the 1:250 000 electronic South African Geology Series maps were used as the baseline for vegetation boundary determination, with geology as the basis. Alluvial bottomlands (mapped as azonal units), shale bands and silcrete and ferricrete patches were captured in detail.

Initially all fynbos (excluding renosterveld and strandveld) units were set to the geological boundaries, at about 250 m resolution. For the many places where recordings existed, the Protea Atlas Project database (which also lists the dominant species, in addition to proteas and importantly also has confirmation of absence of Proteaceae in 'null' plots) was used to help determine the boundaries between Fynbos vegetation and Karoo, and Thicket and Renosterveld vegetation. Vegetation boundaries were checked by ground-truthing the easily accessible regions, and additional mapping of occurrence of proteas was conducted in some of the more novel units.

In some areas (e.g. Robertson Karoo), the vegetation types were delimited by the dominant aspect, rather than separated into northern slopes (supporting predominantly Karoo) and southern slopes (supporting predominantly renosterveld). STEP 'mosaic' units were evaluated and were either used as the basis of a new vegetation type (where phytosociological or Protea Atlas (Rebelo 1991) data supported this), or else subsumed into an appropriate vegetation type (where the mosaic elements were incorporated into the vegetation descriptions, where data existed). Vegetation units with features of both renosterveld and fynbos, were classified as fynbos if the cover of restios exceeded 5–10%, or if Proteaceae (excluding *Leucadendron salignum*) were dominant within the units.

Elevation was used for mapping some units, for example, FFs 30 Western Altimontane Sandstone Fynbos, FFs 31 Swartberg Altimontane Sandstone Fynbos, FFq 2 Swartruggens Quartzite Fynbos and FRs 5 Central Mountain Shale Renosterveld.

Forests

The mapping of forest patches was the least problematic of all vegetation units involved because of the specific structure of forests easily recognisable in the field, on aerial photographs, on satellite images (provided that proper ground-truthing is involved) and in most cases on cartographic products such as physical (topographic) maps at 1:50 000 (and less). Another important element allowing for precise mapping of forests was the available map of forest patches produced by DWAF (Anonymous 1987). This source also known as the Forest

Biome Project Map or simply 'DWAF Map' was available in a GIS format as well. It served as the mapping substrate for the National Forest Classification (Von Maltitz et al. 2003), which yielded 24 Forest Types of floristic-biogeographical character, of which four azonal types were considered stand-alone and the rest were summarised into seven Forest Groups. This classification was based in principle on floristic data such as plots, with (semi)quantitative data on (mainly) woody species. Details of the data collection, collation, elaboration and interpretation leading to the classification scheme were summarised by Mucina & Geldenhuys (2002). Because of unduly great detail for our mapping purposes, the original forest classification (Von Maltitz et al. 2003) was simplified by recognising these seven Forest Groups as well as the original four azonal Forest Types as vegetation units. Furthermore, we have added and mapped one vegetation type that was not part of the National Forest Classification—the Ironwood Dry Forest. The original azonal forest type called 'Licuati Sand Forest' was lumped with Nwambyia Sand Forest (also not part of the National Forest Classification) into a vegetation unit called 'Sand Forest'. Details of the cross-walk between the National Forest Classification of 2003 and the current composition of the vegetation unit on our Map are presented in Table 12.1 in Chapter 12.

The obvious errors of the so-called DWAF Map, especially in the Western Cape, KwaZulu-Natal, Swaziland and northern provinces of South Africa, were corrected using other mapping sources. The forests of KwaZulu-Natal have been re-mapped by FOR-SEA project (Adie & Goodman 2000) and the forests of Mpumalanga by Lötter et al. (2002). The Sand Forest of Maputaland was mapped using coverage based on satellite imagery by Smith (2001). The new data for both provinces available in a GIS format then replaced the original coverage depicted by the DWAF Map (Anonymous 1987). The forest patches of Swaziland were provided by L. Dobson as part of the Swaziland vegetation map (see also Loffler & Loffler 2005). The coverage of the milkwood forests of the Overberg (Western Cape) was provided by D.I.W. Euston-Brown (unpublished data) and that of the Still Bay region (Western Cape) was digitised from a map published by Rebelo et al. (1991). The forest patches on Table Mountain were mapped from a map published by McKenzie et al. (1977). As source of the coverage of the Ironwood Dry Forest (*Androstachys johnsonii*), the Nwambyia Sand Forest as well as some riparian forests along the Limpopo River and its tributaries in the northern Kruger National Park, we used the map by Van Rooyen et al. (1981), digitised by A. Grobler (then Department of Botany, University of Pretoria). The extent of the mangrove forests in the Kosi Bay area was adjusted by digitising the map published by Ward et al. (1986). Additional patches of forest (not depicted by the DWAF Map) were digitised from topographic maps on the basis of information provided by G.P. von Maltitz (Magaliesberg area), L. Mucina (eastern Free State, tallus forests of the Hottentots Holland Mountains and Limietberge), M.C. Lötter (eastern and southern Mpumalanga) and B. McKenzie (Langeberg, Riviersonderend and Outeniqua Mountains).

For the final cartographic presentation on the Wall Map (Mucina et al. 2005) as well as in the Vegetation Atlas (Chapter 18) and correspondingly on the electronic form on CD, the forest patches smaller that 5 ha have been disregarded.

Indian Ocean Coastal Belt

The extent of the IOCB was defined within the borders of the KwaZulu-Natal Province by the extent of the BRG 1 Coastal Belt as mapped by Camp (1999a) for purposes of planning agricultural activities in the province. He distinguished five units within his BRG 1, which we found too detailed to be interpreted unambiguously in terms of our vegetation units. We used floristic data and climate (mainly precipitation and mean annual temperature) to distinguish Maputaland from the rest of the KwaZulu-Natal coast (defined as a composite of the other four Camp subunits within his BRG 1). The borders of the Maputaland Coastal Belt were subject to adjustment based on occurrence of tropical floristic element sand vegetation complexes along the Mtunzini-Mandini coastal segment (as far south as Zinkwazi River mouth) by C.R. Scott-Shaw (unpublished data). The final appearance of the latter unit was further modified by extraction of the azonal units. Embedded within the Maputaland Coastal Belt, the Maputaland Wooded Grassland has been defined on the basis of an unpublished mapping source derived from satellite imagery by Smith (2001). Where the latter source mapped timber plantations, the extent of the former (destroyed) wooded grasslands was reconstructed by C.R. Scott-Shaw using topographic data.

The sandstone-dominated coastal regions of the Ugu District in KwaZulu-Natal and the Pondoland Wild Coast with its sandstone-dominated coastal sourvelds form a natural landscape and vegetation unit, which was already distinguished, also in extent, by Acocks (1953). This vegetation unit strictly follows the extent of the sandstone geology except for the forest and valley bushveld patches mapped as different vegetation units.

The extension of the IOCB along the Transkei coast follows D.B. Hoare & A.R. Palmer (unpublished data), whose approach encompassed multivariate analysis of the vegetation-environment relationships to create a system of land classes to be reclassified later using satellite imagery accompanied by subsequent ground-truthing.

The final appearance of all IOCB vegetation units on the Map (see Mucina et al. 2005) was also influenced by definition of the extant coastal forest patches as well as coastal and inland azonal vegetation units.

Azonal Vegetation

Scanned 1:50 000 maps were used extensively for mapping AZi 5 Bushmanland Vloere, AZi 4 Southern Kalahari Salt Pans and some other pans, wetlands and alluvia. Wetlands mapped for the National Land Cover were used selectively and their extent was also improved through consulting topographic maps. Some alluvia were modified from those mapped for land types (the width of many being reduced, for example, in AZa 5 Highveld Alluvial Vegetation). Some alluvia, estuaries and beaches (seashore vegetation units) were mapped by referring to Landsat 5 images.

A minimum size of 5 ha was generally used for inclusion in the final map, with a general minimum size of 10 ha for selection of many pans. Certain patches smaller than 5 ha such as AZf 2 Cape Vernal Pools were specifically included because they are particularly unique in terms of species.

6.3 Construction of Bioregion and Biome Maps

In preparing the biome and bioregion maps, the bioregions were dissolved to join adjacent polygons in the same bioregion, excluding forest, azonal and infrastructure units. The holes left by excluding forests etc. in the biome and bioregion coverages were filled using the value assigned based on Euclidean Distance in a 200 m grid. Biome polygons smaller than 2 000 ha and bioregion polygons smaller than 600 ha were excluded from the resulting coverage, except for selected smaller polygons such as coastal strips and islands that could not confidently be assigned to another biome. Forests larger than 2 000 ha

were then added to the resulting biome map. The process is described in Figure 2.3.

6.4 Final Production of the Vegetation Maps

Final colours for each vegetation unit were selected attempting to maintain a suite of similar colours within each biome, while trying to ensure good visual distinction between adjacent polygons of different vegetation types at the same time. Colour distinction sometimes required using a very different colour. Additional difficulty arises from the difference between the colour seen on the computer screen and the colour on the printed map, requiring manual adjustment of hue, saturation and value to arrive at suitable printed colours when using the CMYK standard colour model used in offset printing.

The vegetation under the reservoir of dams was reconstructed from evidence of surrounding vegetation and, in certain cases, the topography below the water (by reference to maps that predated the construction of the dam). This coverage can only be viewed on the accompanying CD.

The legend was prepared in a novel way by creating a shapefile with blocks in rows and columns. This enabled colour precision for the legend boxes as well as spacing of headings and subheadings in the legend. Each vegetation type was assigned a column and row value. A table with box identification, row, column and names for biome, group and vegetation type was linked to the polygon (legend box) shapefile. Labels were positioned using these boxes. As the Wall Map was printed in projected units at a scale of 1:1 000 000, the box sizes and spacing were easily calculated based on map units.

The Wall Map was printed by USS Graphics, Cape Town, South Africa, on SAPPI 170 g Magna Gloss paper using 600 dpi PDF files, transferred to offset lithographic plates using computer-to-plate technology. The colour sequence for printing was red (magenta), yellow, black, blue (cyan) and not the normal sequence of black, blue, red, yellow. Colours were converted in ArcGIS to CMYK before PDF files were created. The initial RGB colours did not translate well to CMYK at the printing office, and therefore CMYK colours had to be manually defined in ArcMap. The Wall Map formed the basis for printing the atlas in the current work.

7. Vegetation as a Verbal Model

The verbal model, consisting of descriptive text, is not limited by the constraints of scale inherent in the printed spatial model of the Map. The description has a scale-independent flexibility that can easily allow for inclusion of information on fine-scaled mozaics and can potentially include any nuances that would be impossible to depict on the Map.

Our descriptions of vegetation units are sometimes flanked with short descriptions of groups to which they belong (see for instance Chapter 3 on Fynbos). Each biome is always preceded by an introductory text featuring important physico-geographical, ecological, biogeographical, evolutionary, socio-economical etc. background information on the vegetation units being described (see Chapter 1).

The description of a vegetation unit consists of the following elements:

7.1 Name of Vegetation Unit

Each vegetation unit carries a unique informative name, consisting of four (or three) elements indicating (1) its code,

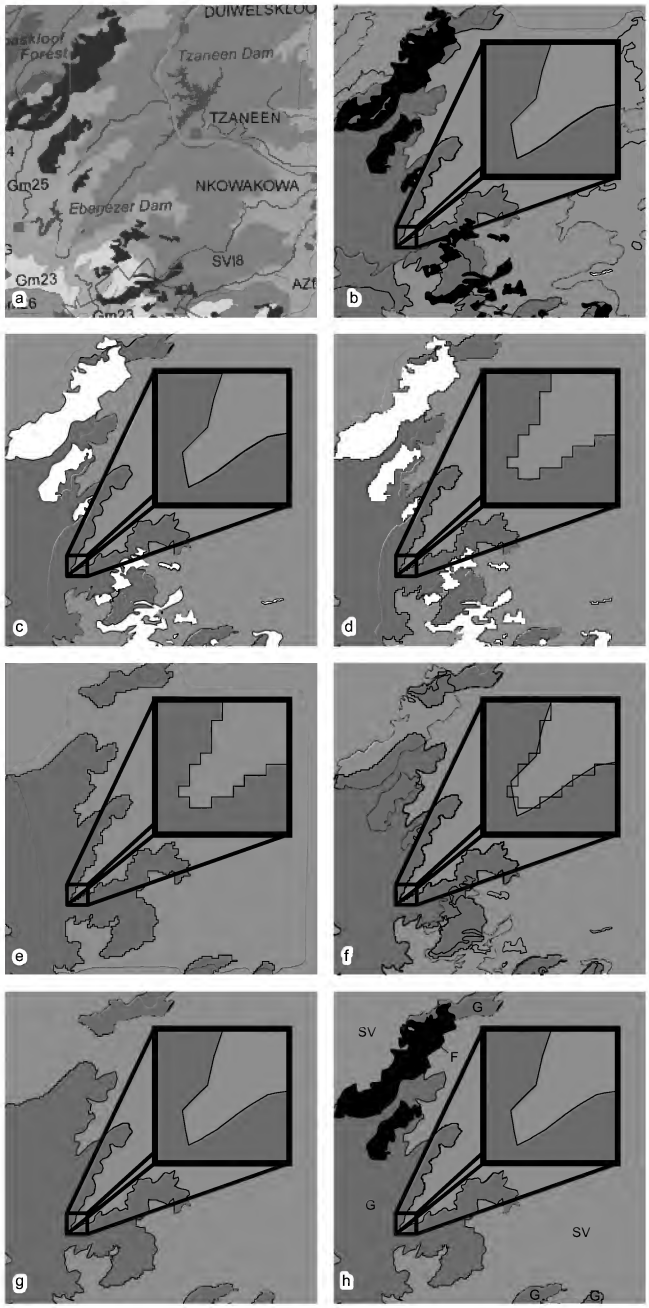

Figure 2.3 The technical steps in mapping the biomes using an example section of the Map. (a) Depicting the vegetation types in the example area. (b) Assigning of vegetation types to biome units and dissolving boundaries between vegetation types within the same biome. (c) Removing Forest, Azonal vegetation types, and polygons that were less than 2 000 ha from any other vegetation types. (d) Converting the resulting polygons to a 200 m grid (raster). (e) Applying the EUCALLOCATION method (ESRI 2006) to fill in the gaps created in (c). (f) Converting the grid back to polygon (vector) and merging with the coverage which had the gaps–see (c). (g) Dissolving boundaries between newly formed slivers of vegetation types within the same biome to obtain smooth boundaries (see magnified section). (h) Restoring Forest polygons greater than 2 000 ha in area.

(2) geographic address, (3) major habitat (often geological) characteristic, and (4) vegetation-structural character. The code provides the context of the unit and is useful for identification of the unit on the Map (see Mucina et al. 2005). Take, for example, FRs 9 Swartland Shale Renosterveld. This code consists of four parts, indicating the classification of the vegetation

unit into a biome (F: Fynbos Biome), bioregion or major group of units (R: renosterveld), and minor group units (s: shale), followed by the numerical code linked to the minor group. In the case of forest, for instance, we recognise two groups (zonal and azonal), hence a code for the scarp forests would read: FOz 5 Scarp Forest (FO: Forest Biome, z: zonal group, 5: unit no. 5 within the zonal group).

Most of the names of our vegetation units consist of three elements, but some are composed of only two words. These are either well-established geographical (and/or ecological) concepts such as 'Ngongoni Veld' and 'Tanqua Karoo', or shorter two-word names that can reflect all information elements necessary. For example, the name 'Lesotho Mires' clearly indicates the geographic address, while the term 'mire' implies major ecological and vegetation-structural characteristics of the unit.

The way of naming the vegetation units was largely motivated by the paper by Cowling & Heijnis (2001), where they used it for naming their Broad Habitat Units (to a large extent spatially and partly also conceptually similar to our vegetation units). It seems, however, that this terminology has a precursor in the work of Campbell (1985) where it was applied in naming fynbos structural units. We have especially borrowed the novel term 'vygieveld' from Cowling & Heijnis (2001), while the term 'gwarrieveld' comes from Vlok et al. (2003).

We have refrained from using the South African-developed vegetation-structural terminology by Edwards (1983) because it is more suited for vegetation units at the habitat scale.

7.2 Spatial Co-incidence with Other Vegetation Maps

The aim of the paragraph on 'synonymy' is to assist the reader in matching the new concepts of vegetation units presented in this work with the older, previously widely used mapped or unmapped vegetation-classification concepts. It simply indicates the level of spatial correspondence with our vegetation units. Acocks (1953, 1988) and Low & Rebelo (1996) cover the same area as our Map and therefore are automatically referred to within this category of spatial overlap. Here we list those Acocks 'veld types' or Low & Rebelo 'vegetation types' that make up an overlap of at least 50%. We used the same spatial-overlap principle to list the units of Moll & Bossi (1984), Cowling et al. (1999) and Cowling & Heijnis (2001) for the Fynbos Biome (and partly also Succulent Karoo), of Vlok & Euston-Brown (2002) and Vlok et al. (2003) for the Albany Thicket Biome (and some units of the surrounding biomes), and finally the zonal units of Edwards (1967) and Camp (1999a, b) encountered in KwaZulu-Natal.

Especially the synonymy of forest, azonal and subantractic units also contains entries of communities at the habitat level derived by various approaches, including the floristic-sociological, numerical, etc. (see for example the synonymy of AZd 3 Cape Seashore Vegetation).

7.3 Distribution

The section on Distribution gives the major distribution of the vegetation unit. It is introduced by the name of the province (in most cases), followed by a reasonably accurate description of locality or localities (but not an account of every polygon in highly fragmented vegetation types) sufficient for the geographically informed reader to get a good idea of just where the type occurs. We used the names and spelling of towns in South Africa as approved by the South African Geographical Names Council (SAGNC) as gazetted before 1 January 2005.

As a rule the indication of the altitudinal range of most of the area occupied by the unit concludes this particular section.

7.4 Vegetation and Landscape Features

This includes the appearance of the landscapes (including terrain type) and the main structural features (dominant growth forms, layering, canopy openness, patchiness, vegetation mosaics etc.) of major plant communities dominant in these landscapes. Particular attention is paid to these features in the case of units with a distinct mosaic of habitats (such as coastal units, alluvial units etc.).

7.5 Geology and Soils (Geology, Soils and Hydrology)

The geological and pedological section contains information on major rocks, both petrographically (rock types) and stratigraphically (age of geologic substrate). Information from GIS overlays between our vegetation coverage and geology was used and interpreted with care (especially with regard to the different scales of sources). Soils are very broadly described (usually using textural characteristics), but where we have sufficient knowledge (based on local pedological studies), we also list major soil types. Information on land types is given for most vegetation types. In many azonal units we use a slightly different heading (Geology, Soils and Hydrology) and we include a description of hydrology (permanent or intermittent flow of streams/rivers, tidal dynamics) and some other factors underlying the azonality of the unit (e.g. salt content). We use the terminology of the South African Committee for Stratigraphy (1980) for geology, the Soil Classification Working Group (1991) for soils and ENPAT for land types.

7.6 Climate

We provide a brief overview statement of the main features of the relevant climate diagram (see Figure 2.2), often including important geographical ranges of parameters (especially MAP and frost). In some cases, one or two actual climate stations in the unit are used to provide mean monthly maximum and minimum temperatures. Any special climatic factors that are not reflected in the climate diagram, for example extreme temperatures, wind or fog, are given.

7.7 Structure of the Species Lists

The species lists are one of the core elements of the description of a vegetation unit. They are primarily aimed at providing information on floristic composition of the plant communities forming the vegetation unit. The categorisation of the species into Important, Biogeographically Important and Endemic adds value to the species lists in terms of biogeography and conservation.

7.7.1 Taxonomic Nomenclature

The names of taxa occurring in southern Africa cited in the descriptions, and throughout the book for that matter, basically follow the recent checklist of the flora (Germishuizen & Meyer 2003) and the PRECIS system. We also use those species names that have been published after appearance of the checklist cited above as well as some other taxonomic concepts that have not yet found acceptance in PRECIS. A number of

Table 2.1 System of growth forms used in the descriptions of the vegetation units.

Category/ Subcategory	Main Traits	Example	Note
Tree	secondary (woody) thickening of tissues; single-stemmed		
Small Tree	lower than 15 m in forests; lower than 10 m in savanna	*Acacia karroo*	excluding Succulent Trees
Tall Tree	taller than 15 m in forests; lower than 10 m in savanna	*Ekebergia capensis*	excluding Succulent Trees
Emergent Tree	taller than 25 m (overtopping canopy)	*Afrocarpus falcatus*	excluding Succulent Trees; only in tall-grown forests
Succulent Tree	succulent stems and branches; taller than 6 m	*Euphorbia triangularis*	
Tree Fern	fern of tree stature; always less than 5 m tall	*Cyathea capensis*	special category of Small Tree
Shrub	secondary (woody) thickening of tissues (at least at base); multistemmed as a rule; when single-stemmed, then branching from base		excluding all epiphytic forms
Low Shrub	lower than 2 m; no parasitic or semiparasitic feeding; non-succulent	*Pentzia incana*	excluding Soft Shrubs, succulent and (semi)parasitic shrubs
Tall Shrub	taller than 2 m; no parasitic or semiparasitic feeding; non-succulent	*Gymnosporia buxifolia*	excluding Soft Shrubs, succulent and (semi)parasitic shrubs
Soft Shrub	secondary (woody) thickening of tissues along main stem; herbaceous tips of branches	*Plectranthus fruticosus*	a transition category between Herbs and Shrubs, typical of some warm-temperate and subtropical forests
Geoxylic Suffrutex	large underground woody 'rhizome'; usually imitating Low Shrub form above ground	*Dichapetalum cymosum*	excluding Shrubs with smaller lignotubers
Succulent Shrub	succulent leaves and/or stems; any height	*Ruschia caroli*	very common among Aizoaceae; including Stem-succulent Shrub, Stem- & Leaf-succulent Shrub and Leaf-succulent Shrub (recognised only in Chapter 6)
Semiparasitic Shrub	green, but parasitising on xylem of other plants; any height	*Thesium hystrix*	growth form limited to few families (mainly Santalaceae)
Semicarnivorous Shrub	feeding on animal waste resembling carnivory	*Roridula gorgonias*	only 2 species of genus *Roridula*
Climber	using other plants as support for climbing or scrambling		also including scrambler and strangler forms; excluding all epiphytic forms
Woody Climber	secondary (woody) thickening of tissues (at least at base)	*Dalbergia armata*	excluding Succulent Climbers
Woody Succulent Climber	secondary (woody) thickening of tissues (at least at base); succulent leaves and/or stems	*Sarcostemma viminale*	rare growth form
Herbaceous Climber	no secondary (woody) thickening of tissues (at least at base)	*Kedrostis nana*	excluding trailing (creeping) or prostrate herbs
Herbaceous Succulent Climber	no secondary (woody) thickening of tissues (at least at base); succulent leaves and/or stems	*Ceropegia*	rare growth form
Graminoid Climber	climbing and scrambling graminoids	*Prosphytochloa prehensilis*	very rare growth form
Herb	no secondary (woody) thickening of tissues; usually primary root system		excluding all epiphytic forms and Soft Shrubs
Megaherb	herbs taller than 3 m	*Strelitzia nicolai*	'bananoid' herbs: tall and with megaphylls
Herb	including annual, pauciennial or perennial herbs		excluding all those showing typical aquatic adaptations, geophytes, succulent, parasitic and carnivorous forms as well as annual plants
Geophytic Herb	presence of herbaceous underground storage organs such as rhizomes, corms, tubers and bulbs	*Lachenalia carnosa*	excluding all aquatic, succulent, parasitic and carnivorous forms
Succulent Herb	succulent leaves and/or stems	*Cleretum papulosum*	including geophytic forms
Parasitic Herb	lack of assimilation apparatus; fully parasitic feeding	*Hyobanche sanguinea*	
Carnivorous Herb	using additional animal (insect) source for some nutrients	*Drosera capensis*	including all aquatic forms (*Utricularia*)
Aquatic Herb	morphological adaptations to spend at least part of life cycle in under-water environment (aerated tissues, reduction of roots etc.)	*Lemna minor*	using water column or water surface as floating medium; including geophytic forms; including subaquatic mosses
Graminoid	'grassy' appearance (long, narrow, mostly tufted leaves); secondary root system		including all Poaceae, Cyperaceae, Restionaceae, Xyridaceae; excluding Juncaginaceae, Thurniaceae and Eriocaulaceae
Graminoid	lower than 2 m	*Aristida congesta*	excluding climbing forms
Mega-graminoid	taller than 2 m	*Phragmites australis*	tall reeds; also including geophytic forms (*Prionium*)
Bamboo	secondary (woody) thickening of tissues (at least at base)	*Thamnocalamus tessellatus*	woody graminoids
Epiphyte	both woody and non-woody; using other plants as substrate, but necessarily as source of nutrients; not rooting in soil		
Epiphytic Herb	no secondary (woody) thickening of tissues		excluding all succulent and (semi)parasitic forms
Epiphytic Succulent Herb	no secondary (woody) thickening of tissues; succulent leaves and/or stems	*Mystacidium*	usually epiphytic orchids; including geophytic forms
Epiphytic Shrub	secondary (woody) thickening of tissues (at least at base)	*Dermatobotrys saundersii*	excluding all succulent and (semi)parasitic forms; very rare category
Epiphytic Parasitic Herb	no secondary (woody) thickening of tissues	*Cassytha ciliolata*	
Epiphytic Semiparasitic Shrub	secondary (woody) thickening of tissues (at least at base)	*Viscum capense*	mistletoes
Other			
Moss	taxonomic category (Bryopsida)	*Bucklandiella valdon-smithii*	
Liverwort	taxonomic category (Marchantiopsida and Anthocerotopsida)	*Symphyogyna marionensis*	
Lichen	taxonomic category including lichenised fungi	*Cladonia pyxidata*	broadly defined category including crustose, fruticose, gelatinous and other types of lichens
Macroalga	taxonomic category (some representatives of Phaeophyta and Charophyta)	*Ecklonia maxima*	

new taxa pending descriptions, but often already in informal use by the botanical community, have also been listed, usually accompanied by the citation of a voucher specimen.

7.7.2 Growth Forms

All species in the lists are classified into growth forms using a system (Table 2.1) developed within the Ecological Flora of Southern Africa Database (L. Mucina, unpublished data). This system is a pragmatic tool based on several major features of the structural and functional life history of plants such as longevity, architecture, height, woodiness, succulence, parasitism, carnivory, epiphytism and the like.

In some chapters similar basic growth forms have been lumped (e.g. 'Small Trees & Tall Shrubs' in the vegetation units of the Indian Ocean Coastal Belt) or split (e.g. 'Stem-succulent Shrubs' and Leaf-succulent Shrubs' in the Desert chapter). This was done because distinction of the growth forms concerned might not always be clear-cut or both growth forms could be equally important in determining the structure of the vegetation.

7.7.3 Important Taxa

The category of Important Taxa includes those species (and lower taxa) that have a high abundance, a frequent occurrence (not being particularly abundant) or are prominent in the landscape of the unit.

The taxa are arranged according to growth forms, the order depending on the overall character of the vegetation concerned: in forests this sequence starts with Tall Trees and ends with growth forms in the undergrowth (Herbs, Graminoids); in succulent shrubland its starts with Succulent Shrubs etc. Mosses and Lichens are always placed at the end. Dominant taxa are given first in the particular lists within each growth form category—these are the species that are dominant (biomass) in the local communities or that are prominent, e.g. conspicuous quiver trees (*Aloe dichotoma*) scattered in a Succulent Karoo shrubland.

This list forms a basic floristic profile of the vegetation unit.

7.7.4 Endemic Taxa

The concept of endemism is determined by the extent of the vegetation unit. This means that a plant taxon is listed as endemic in the description when it occurs exclusively within the unit concerned. We have relaxed the strict interpretation of the 'unit-based endemism' in the Fynbos Biome, where an endemic plant species may have less than 10% of localities outside the vegetation unit in question. In some other biomes we accepted a relatively narrow interpretation of the notion of 'near-endemic' where the clear concentration of the given taxon is within the vegetation unit and a few outliers occur nearby in one or more adjacent units. We are well aware of the fact that the current endemic status of many plants would change in future as our knowledge about distribution of the species becomes more detailed and the extent of our vegetation units becomes more precisely defined. As our vegetation units are naturally defined entities, we consider the use of the term 'endemism' in this sense more appropriate than using this term in a political context (defined by the boundaries of countries or tourist regions).

7.7.5 Biogeographically Important Taxa

Biogeographically Important Taxa (BIT) are those that do not qualify as endemic (see Section 7.7.4), and may qualify as Important Taxa (as defined in Section 7.7.3), but carry an additional important biogeographical message: they are limited to a small group of vegetation units (hence qualify as regionally endemic), they have been listed as regionally endemic in an established Centre of Endemism, they occur at the limits of their (large) distribution area and they show a very disjunct distribution pattern. We decided to single out these taxa to sometimes strengthen the case for delimitation of vegetation units and to indicate their value in raising interesting academic questions and conservation concerns.

Within the Fynbos Biome, with one of the highest concentrations of regional and local endemics, we have refrained from using the category BIT in most of the vegetation units except for those that fall within the CEs with their core in neighbouring biomes (for instance Nieuwoudtville-Roggeveld Dolerite Renosterveld is considered a part of the Roggeveld-Hantam CE, Namaqualand Sand Fynbos is part of the Namaqualand CE). We also use the BIT category for the strandveld units, and here we recognise two (new) putative CEs, namely the West Coast CE and South Coast CE.

Many of the BIT were recruited from the endemics of the putative phytochoria defined as Centres of Endemism (CE) by Van Wyk & Smith (2001). The spatial delimitation of their CEs is largely defined in approximate terms—the boundaries have been painted with a very thick brush (with a notable exception of the Pondoland CE). The (relatively) crisp spatial definition of our vegetation units, however, allows for re-definition of the boundaries of most of the Van Wyk & Smith's (2001) CEs. This revision is in progress (L. Mucina et al., in preparation) and here, when referring to Van Wyk & Smith's concept, we use them already in revised form. We also added some new concepts resulting from our preliminary studies of local endemism based on the list of endemics of our vegetation units.

Some regions of southern Africa house a number of CEs of Van Wyk & Smith (2001). For example, the northern provinces of South Africa (including Gauteng, Limpopo and Mpumalanga, as well as neighbouring Swaziland and parts of Mozambique and northern KwaZulu-Natal) house five of these CEs—nos. 3.1, 6, 7, 8 and 9. We have observed that some species occur in a number of these CEs and are invariably linked to vegetation units that can be summarised under the informal category called 'sourveld' (some of them straddling the borders of the Savanna and Grassland Biomes). This observation led to the definition of a putative endemic category 'Northern Sourveld Endemic'. Examples are *Encephalartos eugene-maraisii* and *Faurea galpinii*; see also a long list of BIT in unit GM 18 Lydenburg Montane Grassland, etc. We have also been able to identify (see Van Rooyen et al. 2001) a group of endemics for the Kalahari. These taxa are limited to deep sands of the Kalahari Basin and reach South African territory in vegetation units of the groups SVk and SVkd exclusively.

Further we have introduced a number of other informal entities, based on groups of vegetation units as delimited in this book, namely:

(a) Central Bushveld endemics (shared by a number of SVcb units), e.g. *Mosdenia leptostachy*s.

(b) Kalahari endemics (shared by a number of SVk and SVkd units), e.g. *Panicum kalaharense, Neuradopsis bechuanensis*.

(c) Camdebo endemics, e.g. *Duvalia modesta*.

(d) Capensis elements (species of typical Cape clades; Linder (2003), occurring in other than Fynbos units), e.g. *Muraltia, Raspalia, Watsonia* and many others in Pondoland.

(e) Northern KwaZulu-Natal endemics (sharing several Gs or SVs units of this region), e.g. *Cissus cussonioides.*

Important long-distance biogeographical links such as a link to mountains of Zimbabwe (e.g. *Eriosema buchananii, Nemesia zimbabwensis*) were useful in classifying some species as carrying an important biogeographical message.

Widely distributed species occurring at the limits of their distribution, such as those reaching southern Africa from the northern hemisphere (*Lycium shawii*), were also noted in BIT category in places.

7.8 Conservation

This section collates important information available on the conservation issues related to the vegetation unit. Here we mention the conservation status (using the scale of categories of Critically endangered, Endangered, Vulnerable, Least threatened after Golding 2002), conservation target and percentage of the surface of the unit currently under protection (listing also the main statutory and private conservation areas). Threats to the unit such as the occurrence of major (mostly woody) alien species and the erosion status (from the Predicted Soil Loss data of the national Department of Agriculture) are also given. The five categories of levels of erosion (soil loss) are as follows: very high (> 60 t/ha/a — tons per hectare per annum), high (26–60 t/ha/a), moderate (13–25 t/ha/a), low (6–12 t/ha/a) and very low (0–5 t/ha/a).

7.9 Remarks

The sections on Remarks are devoted to (1) discussion of any important issue mentioned in the description in more detail, (2) interesting biogeographical phenomena and oddities, (3) problems of delimitation, (4) level of our knowledge about the unit, and any other aspect of particular interest pertaining to the unit.

7.10 References

This section lists (in alphabetical and then chronological order) all references that feature vegetation patterns pertinent to the vegetation unit concerned. We also added some references otherwise useful to elucidate ecology and distribution of the unit or some of its important species. We also attempted to list many 'grey-literature' sources, such as major unpublished reports, university theses and projects. Where no published information was available, we cited the source(s) of unpublished data.

8. Concluding Remarks

Although vegetation surveys and mapping are not the most fashionable topics of contemporary plant ecology (especially outside Europe), their power in providing quick and reliable simplified models of vegetation patterns that assists in important decisions on nature management and on other land uses, is indisputable. The need for understanding (using, protecting, managing) vegetation patterns encourages and will continue to fuel the development of new tools and procedures of vegetation survey. Progress in vegetation mapping will continue to focus more closely on the acquisition and interpretation of remote-sensed data and stocking and utilisation of databanks to assist in the spatial data analysis. We hope that extensive use of our Map (and the accompanying Book) will further enhance especially detailed vegetation surveys—an invaluable source of data for any mapping project, especially when planned and co-ordinated for incorporation in a national scale network. We believe, as we have already alluded to in the Introduction chapter, the VEGMAP is a process; we shall be closely monitoring new methodical developments in vegetation survey and mapping for new editions of both our Map and the Book.

9. Credits

The ideas presented in this chapter are a result of co-operation between members of the core VEGMAP team (M.C. Rutherford, L. Mucina, L.W. Powrie) and by the regional mapping teams and other contributors at large. L. Mucina wrote Sections 1, 2, 3, 4, 7, 8 and 9 and compiled the list of References (Section 10). All these sections were edited (both conceptually and technically) by M.C. Rutherford and L.W. Powrie, whose contribution was vital both to the contents and presentation of all these sections. M.C. Rutherford and L.W. Powrie (assisted by L. Mucina) compiled the text of the Sections 5 and 6. The complex subsection 6.2.2 (featuring the specific examples of mapping various biomes) was written by M.C. Rutherford (assisted by L.W. Powrie) for Albany Thicket, Grassland and Savanna, Azonal vegetation, Fynbos, and most of the arid biomes. In this subsection, L. Mucina contributed text on Forests, Indian Ocean Coastal Belt and Nama-Karoo (part of the arid biomes) as well as on Azonal vegetation.

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Biomes and Bioregions of Southern Africa

3

Michael C. Rutherford, Ladislav Mucina and Leslie W. Powrie

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Figure 3.1 Visual collage of biome diversity.

K. Phillips & L.W. Powrie

1. Biomes

1.1 The Biome Concept

The terms biome, ecoregion and bioregion of academic ecology are becoming increasingly used by those concerned with management and conservation of natural resources. These units have broad-scale applicability to those who have to develop conservation and management strategies over large areas. This chapter attempts to re-define the biome classification of the region encompassing South Africa, Lesotho and Swaziland in the context of the new vegetation map in the atlas section of Chapter 18. We also introduce the first consistent classification of 'bioregions'—subordinate units to a biome.

The key to understanding the concept 'biome' is rooted in the issue of scale and in the concept 'biotic community'. The concept 'community' ('biotic community') itself is marred by a history of inconsistent use and interpretation to such an extent that some view it as a nonconcept (Peters 1991). If we define 'community' very broadly as *an assemblage of living organisms sharing the same portion of space during a certain period of time*, then this all-encompassing definition applies to biome as well. The real difference is in scale. Biome is viewed as a high-level hierarchical (hence simplified) unit having a similar vegetation structure exposed to similar macroclimatic patterns, often linked to characteristic levels of disturbance such as grazing and fire. The biome can be considered a kind of 'subcontinental biotic supercommunity'. Cox & Moore (2000) call it a 'large-scale ecosystem'. As a high-level hierarchy unit, biomes are not characterised by individual species (which appropriately characterise units at the more detailed lower hierarchical levels) but mainly by the emergent properties of vegetation structure and associated climate or any other applicable broad-scale environmental factors (O'Neill et al. 1986). Hierarchy theory also suggests that higher-level spatial hierarchy scales (such as biomes) are associated with longer-term time scales although there is a complex interplay between evolutionary (long-term) and ecological (short-term) time scales. Rutherford & Westfall (1986, 1994) provided (at that stage) an exhaustive review of the complexity in defining biomes, also referring to five criteria (maximum global limits, mapping scale limits, primary and secondary bases for classification, and excluded areas) described further below. The main proponents in biome (or an equivalent) definition were either those emphasising the overriding role of climate acting at broad scales (Schimper 1898, 1903, Rübel 1930, Schimper & Von Faber 1935, Weaver & Clements 1938, Holdridge 1947, 1967, Walter 1973, 1976, Whittaker 1975, Walter & Box 1976, Walter & Breckle 1991, Rivas-Martínez 1995, Polis 1999, Krebs 2001) or those using a combination of life forms matching (not always perfectly) the major climatic patterns (Box 1981, 2002, Rutherford & Westfall 1986, 1994, Cox & Moore 2000, Mucina 2000).

The quantitative link between climate and life form combinations serves as basis for construction of biome models making use of key ecophysiological principles (see below). Bond et al. (2003, 2005), Woodward et al. (2004), Bond (2005) and Bond & Keeley (2005) found that the extent of the modern biomes (especially in C_4-dominated grasslands, savanna as well as in fynbos—all 'fire-driven ecosystems' (FDE) *sensu* Bond et al. 2003) is at variance with classical climate potential models of biomes. These findings strongly suggest that the biome concept has to be revised to recognise the role of large-scale disturbance as an important factor shaping the zonal vegetation.

Strictly speaking the term biome includes both plant and animal communities, as its original American roots (Clements & Shelford 1939) suggest. Because of the dominant nature of vegetation cover in (nearly) all terrestrial ecosystems, biomes have been based only on vegetation characteristics.

In vegetation ecology, the concept of a plant community on a (sub)continental scale was called a 'formation' (Grisebach 1872, Dansereau 1957, Fosberg 1961, Mueller-Dombois & Ellenberg 1974; see Beard 1978 for a review). Probably because the term 'formation' was later used as part of formal syntaxonomic hierarchies of the American and Russian schools (compare Whittaker 1978 and Aleksandrova 1978) in very different ways, the term has largely been abandoned by the scholastic community or is used in an informal context. Although our 'biomes' are thus structural 'formations' in the original sense of Grisebach (1872), we prefer the former term.

This chapter introduces some of this information but mainly compares our units with those of other previous approaches and also makes certain comparisons (including climatic) across our biomes. This main focus is also applied to our bioregions that lie at a level between the biome and the vegetation types. Details on each biome are given in the respective chapters of this book.

1.2 Biomes of Southern Africa: Major Patterns

Southern Africa boasts a wide range of biomes. The relatively moist, mostly winter-rainfall region, encompassing the Fynbos Biome in the west and its drier climatic counterpart termed the Succulent Karoo Biome, forms the smallest of the world's six floristic kingdoms (Takhtajan 1986, but see Cox 2001), often draped over the Cape Fold Mountains and sandy lowlands of the southwestern Cape. The Succulent Karoo Biome of the Richtersveld, Namaqualand and the Little Karoo has not only the highest diversity of succulent plants in the world, but is the most species-rich semidesert on our planet. The summer-rainfall Savanna Biome of the north and east of the region represents the southern extension of the largest biome of Africa. The summer-rainfall Grassland Biome of the cooler, elevated interior is poorly represented elsewhere in Africa and is home to a wealth of species limited to southern Africa. The unique Indian Ocean Coastal Belt (IOCB) of South Africa with its recurrent extant enclaves of forest represents the southernmost extent of coastal (sub)tropical forests of the wet, tropical and subtropical seaboard of East Africa. The Desert occupies a small extent of our mapping area in the extreme northwest but, importantly, forms the southern tip of the winter-rainfall domain of the Namib Desert as well as a summer-rainfall Gariep Desert with affinities to the central-north parts of the Namib Desert. The Albany Thicket Biome, with a combination of plant forms intermediate between Savanna, Nama-Karoo and Subtropical Forest, represents an unusual structural, floristic and evolutionary ancient type of note in the subcontinent. The mostly summer-rainfall Nama-Karoo Biome is possibly the least species-rich, yet it holds many intriguing relationships with its six directly neighbouring biomes. The Afrotemperate Forests in southern Africa are highly distinctive and are also characterised by their small and patchy occurrence over the wetter parts of the winter- and summer-rainfall areas of the region. They are clearly part of the global warm-temperate forest biome. Most of these patches are too small to be shown in Figure 3.2. The Subantarctic Tundra and Polar Desert Biomes on the Prince Edward Islands in the Southern Indian Ocean are discussed in Chapter 15 and are not referred to further in this chapter.

The two most cited sets of previous works on biomes in southern Africa are Rutherford & Westfall (1986, 1994) and Low & Rebelo (1996, 1998) following on the seminal work of Huntley

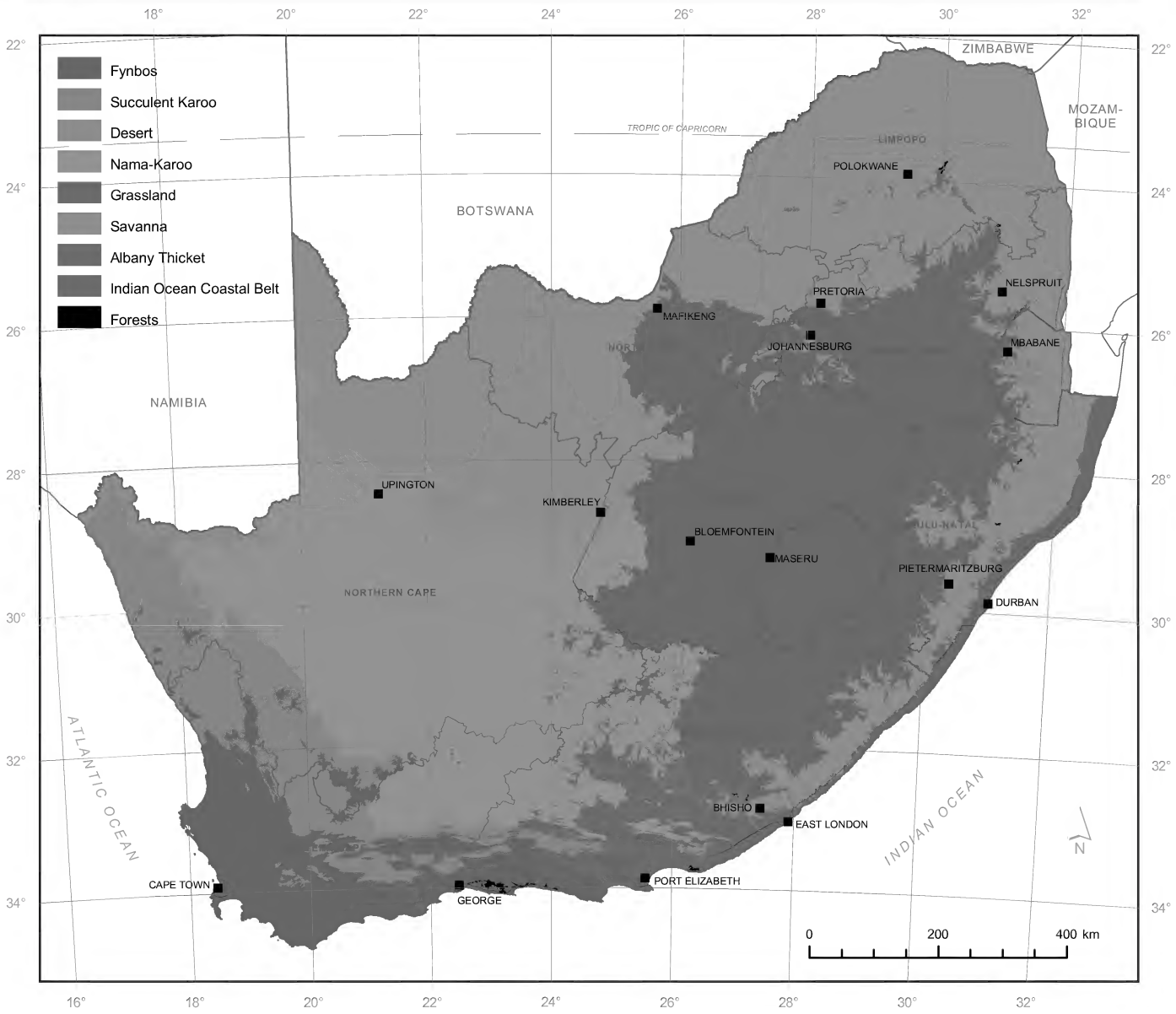


Figure 3.2 Biomes of South Africa, Lesotho and Swaziland.

(1984). The biome concept has been examined in some detail in Rutherford & Westfall (1994) and Rutherford (1997) and applied to southern Africa. In contrast to Low & Rebelo (1996, 1998), the criteria Rutherford & Westfall (1994) applied for a biome were explicit and derived from the globally applicable literature (e.g. Hansen 1962, Odum 1971, Smith 1974, Godman & Payne 1979).

Rutherford & Westfall (1994) emphasised that:

(1) A biome is the largest land community unit recognised at a continental or subcontinental scale and therefore does not recognise any subsets of a biome as a 'biome of lower rank'.

(2) Biome patches should be of a viable and minimum size (also to acknowledge the zoological components of a biome) (about 20 km in shortest cross distance).

(3) Biomes are defined primarily on combinations of dominant life or growth forms and not on the basis of taxonomic characteristics (floristic nor faunal) or nondominant elements.

(4) Biomes are defined secondarily on the basis of major climatic features that most affect the biota, i.e. not climatic indicators that may happen to correlate with the biome but are ecologically insignificant or irrelevant.

(5) Biomes do not include unnatural or major anthropogenic systems, although systems irreversibly changed by man (e.g. long-term, severe overgrazing) that are self-sustaining in their present state, are included.

The current work deviates only from the second and third criteria above largely because we are here deliberately biased towards vegetation and its floristic diversity. Only botanical elements are considered (with no consideration of faunal elements nor of their scale requirements—home ranges etc.). The biomes are made up of vegetation units defined on floristic criteria (not purely structural criteria) and no scale limitation was recognised (other than that the vegetation unit should be above the level of plant community). The biomes are partly derived from a bottom-up approach which accounts for the perfect match between biome boundaries and floristically determined boundaries. This should not distract from the broad yet distinctive floristic links with structurally determined biomes as shown by Gibbs Russell (1987), ultimately also by our approach. The biomes are also clearly in keeping with the climatic criteria of biomes and they

correlate with climatic parameters that are biologically meaningful (see below).

The current work recognises two biomes in addition to those of Rutherford & Westfall (1994) and Rutherford (1997). The first is the Albany Thicket Biome which Rutherford & Westfall (1994) referred to as unmappable 'dwarf forest' of the Eastern Cape and included in their Savanna Biome. This biome partly corresponds to the Low & Rebelo's (1996) 'Thicket Biome', but the latter was much more extensive than the Albany Thicket Biome (including much of the Western Strandveld; see Chapter 4 on Fynbos). The second newly distinguished biome is the much transformed IOCB which was mapped as Savanna by Rutherford & Westfall (1994) but, as also pointed out by them (p. 74), was regarded as not fully satisfactory in the area. In this area, the current work retains as Savanna Biome only the inland strip parallel to the IOCB. Given no constraints of scale, the present work also includes many groupings of azonal vegetation units, which are not regarded as part of any biome in zonal terms, but appear as biomes merged into the background on both (scale-limited) biome and bioregion maps. Many biome boundaries are different owing to the different criteria used and to availability of new information, yet many of the boundaries remain nevertheless broadly similar. The greatest relative change (increase) in area of biome compared to that of Rutherford (1997) is in the Desert and Afrotemperate Forests. The most northerly and driest parts of the Succulent Karoo Biome of Rutherford (1997) in the vicinity of the lowest reaches of the Orange River are now regarded as part of a winter-rainfall Desert (although it is clear that at least some patches of the Succulent Karoo Biome will be upheld northwards in southwestern Namibia). Degrees of correspondence between the currently recognised biomes and other recent biome classifications are given in Table 3.1.

1.3 Biogeographical Approaches

There have been a number of other large-scale compartmentalisations into natural areas of our mapping area that approximate our biome scale.

White (1983) distinguished five phytochoria (phytogeographical units) in our region based on richness of their endemic floras at the species level. Degrees of correspondence between the biomes and the phytochoria of White (1983) are given in Table 3.2. There is fair correspondence between the Cape Phytochorion and the Fynbos Biome as well as between the Guineo-Congolian Phytochorion (Usambara-Zululand Domain) and the IOCB. White (1983) recognised most of the more mesic parts of the Grassland Biome as part of his Afromontane Phytochorion.

Gibbs Russell (1987) clearly showed that floristic links were closer between the Succulent Karoo Biome and the Fynbos Biome than between the Succulent Karoo and the Nama-Karoo Biomes. Linder et al.'s (2005) analysis divided our Savanna Biome into an eastern and northern form on the one hand and a Kalahari form (including western parts of the Central Bushveld Bioregion) on the other.

Siegfried (1989) provided a map of the biomes of our mapping region based on Rutherford & Westfall (1986) and for the savanna areas on Huntley (1984). The savanna areas here and in Huntley (1997) were divided into Arid Savanna and Moist Savanna Biomes. These two functionally important groupings are discussed further in the Savanna Chapter in this book.

Burgess et al. (2004) provided a map of the ecoregions of Africa and some of these units as well as some or their hierarchically higher units relate to our biome level. In this section we examine the relationship between their work and our work at biome level. First, it is important not to confuse our terms and concepts of 'biomes' and 'bioregions' with those used by Burgess et al. (2004). They group their most detailed-level units (ecoregions) into a dual hierarchy. (Discussion of various approaches to 'ecoregions' is found in section 2.2 on Bioregions.) In a biogeographical framework they group ecoregions into 'Bioregions' which in turn are grouped into 'Realms'. Within a 'habitat framework' they group ecoregions into 'Sub-biomes' which in turn are grouped into 'Biomes'. Within our mapping area, they recognise only two 'Bioregions'. Areas corresponding to our Fynbos and Succulent Karoo Biomes fall within a 'bioregion' called 'Cape Floristic Region' while the remaining area is part of a bioregion called 'Eastern and Southern Africa'. In our mapping area their 'bioregion' level, contrary to ours, generally lies above that of our biomes and, indeed, their biomes. It is unfortunate that Burgess et al. (2004) failed to be more explicit about their classification criteria. Their terminology shows a curious mixing of phytogeographical and vegetation-ecological systems.

Burgess et al. (2004) recognised six biomes in our mapping region:

Table 3.1 Correspondence between recent biome classifications for South Africa, Lesotho and Swaziland and those presented in the current work.

Biome	Overlapping area (%)			
	Rutherford & Westfall (1986)	Low & Rebelo (1996)	Rutherford (1997)	Simplified biome map (Figure 3.2)
Albany Thicket	0	50	0	100
Desert	0	0	8	100
Forests	23	78	23	100
Fynbos	76	81	75	100
Grassland	85	82	85	100
Indian Ocean Coastal Belt	0	0	0	100
Nama-Karoo	94	93	94	100
Savanna	82	88	80	100
Succulent Karoo	75	78	75	100

The biome termed 'Mediterranean Forests, Woodlands, and Scrub' comprises their 'Albany Thickets' (sic), 'Lowland Fynbos and Renosterveld' and 'Montane Fynbos and Renosterveld' bioregions (and in South Africa these are not divided into sub-biomes). 'Lowland Fynbos and Renosterveld' and 'Montane Fynbos and Renosterveld' together closely approximate the extent of the Fynbos Biome (82%). There is some agreement regarding the core area of the Albany Thickets Ecoregion and the Albany Thicket Biome, but overall correspondence is only 33% (Table 3.3).

The biome termed 'Deserts and Xeric Shrublands' includes areas corresponding to our Desert, Succulent Karoo and Nama-Karoo Biomes as well as to two of our Savanna Bioregions, namely Eastern Kalahari Bushveld and Kalahari Duneveld. Their biome is not divided into

Table 3.2 Degree of correspondence (%) between the biomes and phytochoria after Linder et al. (2005) and White (1983).

	Biome								
Phytochorion	Albany Thicket	Desert	Forests	Fynbos	Grassland	Indian Ocean Coastal Belt	Nama-Karoo	Savanna	Succulent Karoo
Linder et al. (2005)									
Cape	55		56	77			2		44
Eastern Karoo	21				45		15	24	
Kalahari					5			19	
Karoo Transition							5	4	
Namib-Karoo		100		6	1		77	3	47
Natal	14		29		49	69		46	
Somalian								1	
Zambesian-Central			3					2	
Not classified	10		12	17		31		1	9
White (1983)									
Zambezian			3		2			33	
Cape	10			68			1		11
Karoo-Namib	13	100		25			74	3	89
Afromontane			70	5	17			2	
Kalahari/Highveld	16		5		69		25	43	
Tongaland-Pondoland	61		21	2	12	96	1	19	
Not classified						4			

sub-biomes in South Africa. There is a close correspondence (in South Africa) between their 'Nama Karoo Ecoregion' and the Nama-Karoo Biome (91%) and there is also a reasonably close correspondence between the 'Succulent Karoo Ecoregion' and the Succulent Karoo Biome (77%).

The biome 'Montane Grasslands and Shrublands' corresponds generally to our Grassland Biome, but Burgess et al. (2004) include in their biome their 'Maputaland-Pondoland Bushland and Thickets' Ecoregion, which corresponds closely to our Eastern Valley Bushveld and Thukela Bushveld. With this anomaly excluded, there is an 88% correspondence with the Grassland Biome. They differentiate the high-altitude grassland of the Drakensberg from the rest of the grassland as an 'Alpine Moorland' Sub-biome.

The biome termed 'Tropical and Subtropical Grasslands, Savannas, Shrublands, and Woodlands' corresponds generally to our Savanna Biome (with the notable exception of our Kalahari Bioregions and Zululand Lowveld areas). They differentiate their biome into two sub-biomes, namely '*Acacia* Savanna Woodland' and 'Mopane Woodland'.

Their biome called 'Tropical and Subtropical Moist Broadleaf Forests' corresponds approximately to our Afrotemperate Forests together with the IOCB. At the sub-biome level they separated an 'Afromontane Forest' from an 'Eastern African Lowland Forest-grassland Mosaic', the latter corresponding more closely to our IOCB (87%). In South Africa we recognise their 'Mangroves Biome' only as an azonal vegetation type—Mangrove Forest. Within this unit in South Africa, they do not differentiate at sub-biome level.

Using a cluster analysis of plant species distributions from a variety of sources, Linder et al. (2005) derived seven phytochoria within or entering our mapping domain. These are: (1) 'Namib-Karoo' in Namaqualand, most of the Karoo interior and southern Namibia; (2) 'Cape' in the Western and Eastern Cape Provinces and approximating the area of the Fynbos Biome; (3) 'Kalahari' in the northern parts of the Northern Cape Province and western parts of the North-West and Limpopo Provinces and extending through Botswana to cover most of central and northern Namibia; (4) 'Karoo transition' in scattered parts in the north of the Northern Cape and central Botswana; (5) 'Eastern Karoo' over most of the Free State and some adjoining areas in the North-West and Northern and Eastern Cape Provinces; (6) 'Natal' along the eastern seaboard east of the main escarpment from around East London northwards, including nearly all of KwaZulu-Natal and Mpumalanga, all of Gauteng and most of Limpopo Province; and (7) 'Zambezian-central' in the northeastern extremity of South Africa extending north of the Limpopo through the eastern half of Africa to northern Tanzania. Table 3.2 gives the degree of correspondence of these phytochoria with our biome units. There is good correspondence between the Cape Phytochorion and the Fynbos Biome and fair correspondence between the Eastern Karoo Phytochorion and the less mesic parts of the Grassland Biome. However, the Natal Phytochorion does not distinguish between Savanna, IOCB and the more mesic parts of the Grassland Biome. Similarly, the Namib-Karoo Phytochorion does not distinguish between the Desert, Succulent Karoo and Nama-Karoo Biomes which Linder et al. (2005) suggest may be due to under-sampling and to the coarse resolution of their sampling.

1.4 Biome Modelling

Many other approaches to defining biomes include modelling. Equilibrium models for predicting biome distribution represented the first generation models where biome or biota distribution was assumed to be in equilibrium with climate. Holdridge (1947) was the first to attempt to provide a global classification and distribution of life zones (biomes) based on two climatic parameters. Holdridge's classification (and some other similar schemes, e.g. Whittaker 1975) assumes that biomes act as an amorphous whole—in other words, they are not made up of individual components with different climatic sensitivities. A pioneer and remarkably comprehensive equilibrium model was constructed by Box (1981) who defined close

Table 3.3 Degree of correspondence (%) between the biomes and ecoregions of Burgess et al. (2004). *Full name: Tropical and Subtropical Grasslands, Savannas, Shrublands, and Woodlands.

	Biome								
Biome and Ecoregion according to Burgess et al. (2004)	Albany Thicket	Desert	Forests	Fynbos	Grassland	IOCB	Nama-Karoo	Savanna	Succulent Karoo
Deserts and Xeric Shrublands	**16.1**	**100**		**12.9**	**8.3**		**95.1**	**39.1**	**90.2**
Kalahari Xeric Savanna					0.7		2.5	37.3	
Nama Karoo	15	76.8		1.9	7.6		91.3	1.8	13.1
Succulent Karoo	1.1	23.2		11			1.3		77.1
Mangroves						**5**		**0**	
Southern African Mangroves						5		0	
Mediterranean Forests, Woodlands, and Scrub	**37.8**		**2.4**	**84.7**	**0**		**0.9**	**0.1**	**9.7**
Albany Thickets	32.8			2.5	0		0.9	0.1	2.1
Lowland Fynbos and Renosterveld	2.6		0.7	37.2					0
Montane Fynbos and Renosterveld	2.5		1.7	44.9					7.6
Montane Grasslands and Shrublands	**35.5**		**19.1**	**0.5**	**89.4**	**7.7**	**4**	**17.6**	
Drakensberg Alti-Montane Grasslands and Woodlands					3.3				
Drakensberg Montane Grasslands, Woodlands and Forests	27.8		14.3	0.4	38	2.5	3.7	10.9	
Highveld Grasslands					47		0.3	3.8	
Maputaland-Pondoland Bushland and Thickets	7.8		4.8	0.1	1.1	5.2		2.9	
Tropical and Subtropical Grasslands, Savannas*			**13.8**		**2.1**			**40.2**	
Kalahari Acacia-Baikiaea Woodlands								2.5	
Southern African Bushveld			6.2		0.9			26.4	
Zambezian and Mopane Woodlands			7.6		1.2			11.2	
Tropical and Subtropical Moist Broadleaf Forests	**10.4**		**64.2**	**1.8**	**0.1**	**86.8**	**0**	**3**	
Knysna-Amatole Montane Forests	1.3		58.5	1.8	0.1		0	0	
KwaZulu-Cape Coastal Forest Mosaic	9		5.7		0	59.4		1.2	
Maputaland Coastal Forest Mosaic						27.4		1.8	

to 100 different plant types and the climatic tolerance ranges of each in terms of an array of climatic variables. He used these to map the combinations of these types globally with reasonable success at the macroscale. A similar, but more practically simplified 'functional group' approach was more formally applied in the BIOME foundation model (Prentice et al. 1992), in which 13 functional groups of plants were defined and related to four major bioclimatic controls. The results for the area of South Africa partly matched some of the biomes, but were at variance with a number of others. Subsequent models included coupled models which derive vegetation type (and structure) and biogeochemical fluxes. Examples include BIOME3 (Haxeltine & Prentice 1996) incorporating various physiological and ecosystem processes (see Hallgren & Pitman 2000 for a critical evaluation). This model has evolved into BIOME4, which attempts to cover the diversity of biome types better (Cramer 2002). Choice of climatic variables is crucial. Leemans (1997) observed that the more superior global vegetation models all included a realistic water balance and/or seasonality. Despite the application of many forms of a priori-defined functional types above, defining functional types remains a 'major problem' and 'experiments or natural perturbations may be the only approach which can differentiate functional types; structure may not be a reliable key' (Woodward & Cramer 1996).

Interest in biome models as mentioned above comes to a large extent from the need to estimate likely changes in carbon stores in the terrestrial biosphere, as a consequence of atmospheric carbon dioxide increase and the associated changing climate (Cramer 2002). In other words, there is likely to be less interest in the precision of boundaries of biomes and the identity of small but floristically important biomes such as the Succulent Karoo. It has also been recognised in some global models that shrubland biomes are more difficult to predict (Woodward et al. 2004).

Clustering climatic ranges of plant taxa have been used to produce 'Bioclimatic Affinity Groups' (Laurent et al. 2004), resulting in the co-occurrence of several such units in the same area. But such multiranging units were not synthesised into units of vegetation assembly.

Biomes and other categories have limitations depending on purpose. 'Categories such as that of ecoregions tend to become self-fulfilling prophecies when experimental designs assume their validity instead of testing their usefulness' (Magnussons 2004). Also, the longer-term identities of biome units have to be questioned where there is ample evidence that biomes in the past have not moved as a whole in response to climate change (Huntley 1991) and most models of the effects of future climate

change expect species to respond independently of their currently associated species, e.g. see Iverson et al. (2004).

1.5 How the Biomes Compare

More detailed descriptions and considerations of each biome are given in the introductory sections of each biome chapter. Here we concentrate on comparisons across biomes.

The biomes are highly disparate in size. Relative areas of the biomes are given in Figure 3.3. There are three large biomes, namely Savanna, Grassland and Nama-Karoo, together accounting for almost 80% of the total area, while Desert and Afrotemperate Forest together account for less than 1% of the area.

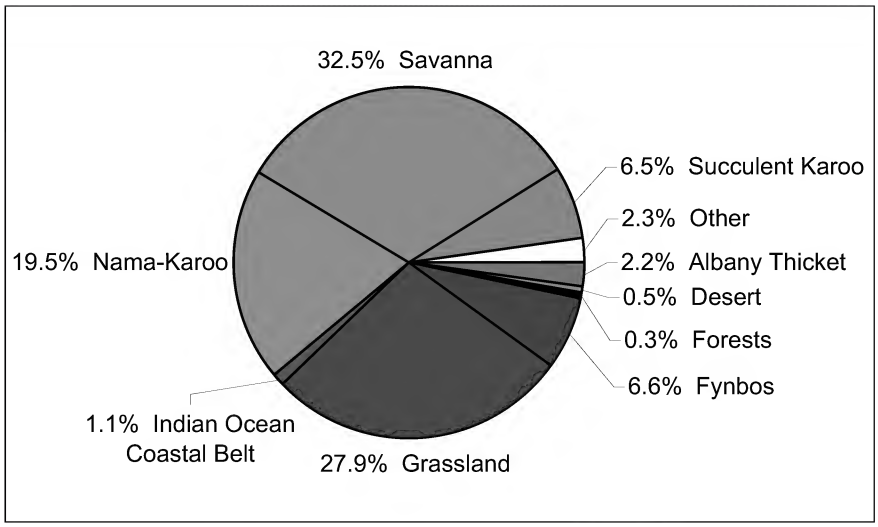


Figure 3.3 Relative proportions of areas of the biomes.

Albany Thicket has the greatest diversity of biome neighbours and borders on seven other biomes (Figure 3.4). This, together with the highly dissected nature and considerable length (> 15 000 km) of the perimeter, allows for possibly high species diversity collectively along this ecotone. Desert borders on the fewest biomes within South Africa (Succulent Karoo and Nama-Karoo), which is what would be expected from the most climatically extreme biome. Just over 40% of potential contacts between biomes in the simplified map (see Chapter 2) do not occur in the region (Figure 3.4). Thus there is little potential exchange of flora between, for example, the Grassland and Succulent Karoo Biomes. Only three of the biomes (Nama-Karoo, Grassland and very marginally Savanna) do not border on an ocean (or at a larger scale on the vegetation of the coastal strips; Chapter 14). Despite Afrotemperate Forest accounting for the smallest biome area of only 0.3% (Figure 3.3), it has the third longest boundary with biomes in the region (Figure 3.4), illustrating its highly fragmented state. More than two thirds of the land boundary of the Succulent Karoo is shared with Fynbos. Much of this interface is highly irregular, thus possibly promoting some floristic intermingling between these two biomes over time (see also below on sharing of taxa). More than half the boundary of Desert borders on Succulent Karoo (in South Africa), while almost half of that of Savanna borders on Grassland.

Boundaries between biomes vary from sharp to very gradual. Examples of sharp boundaries between biomes include those sometimes over only tens of metres between Fynbos on parts of the Cape Fold Mountains and the Succulent Karoo at lower altitude. More intermediate boundaries of a few kilometres wide are often found between the Succulent Karoo and Nama-Karoo Biomes. Very gradual transitions of tens of kilometres can be found, e.g. in some parts of the southern Kalahari between the Nama-Karoo and Savanna Biomes. In a few isolated cases, membership of a biome is equivocal, for example, for some vegetation types at the interface between the Sub-Escarpment Savanna and Sub-Escarpment Grassland of KwaZulu-Natal.

Most of the biome units of this study are incomplete and continue north of the political boundaries of this work. These are: Desert, Afrotemperate Forest, Grassland, IOCB, Nama-Karoo, Savanna and Succulent Karoo. Only Albany Thicket and Fynbos are fully circumscribed within our geographical area. Savanna has by far the longest border with other unmapped savanna to the north of our region (Figure 3.4).

The number of vegetation units per biome varies widely (Figure 3.5a) and is roughly in proportion to the floristic diversity of the biome. Hence the Fynbos Biome with the highest number of vegetation units (119) also has the highest number of species and a high proportion of endemic species (Gibbs Russell 1987). The Nama-Karoo Biome with only 14 vegetation units is also generally species-poor in comparison to other biomes. The IOCB may appear to be somewhat under-represented in terms of number of vegetation types currently recognised, yet on a unit area basis at 0.5 vegetation units per 1 000 km^2, it is intermediate between Savanna and Albany Thicket (Figure 3.5b). Although the diversity and the number of vegetation types in the Desert Biome is probably boosted by almost 90% of its types bordering directly on the relatively species-rich Succulent Karoo Biome, the relatively high number of types in the biome may also reflect a treatment at a greater level of detail. At the same time, the somewhat lower number of vegetation types per unit area in the Fynbos Biome probably reflects the significant under-sampling in the biome. The mean area of vegetation types per biome is by far the greatest in Nama-Karoo and smallest for Afrotemperate Forest (Figure 3.5c). The vegetation types in Desert and Fynbos are only marginally larger than those in Afrotemperate Forests, again emphasising the high species diversity and its level of geographical clustering in Fynbos (see above regarding detail in Desert).

Gibbs Russell's (1987) analysis of the species (and infraspecific taxa) richness of those biomes compatible with those of this book (and omitting biomes that were included in her analysis north of our mapping area) showed the Fynbos Biome to be the most rich with 7 316 taxa (currently with biome edges including almost 9 000 taxa) and about 52% of this amount in Grassland Biome and 29% in the Succulent Karoo Biome. About 67% of Fynbos Biome taxa, 28% of Grassland Biome taxa and 29% of Succulent Karoo Biome taxa were endemic. There was greatest sharing of taxa between the Succulent Karoo and Fynbos Biomes and least sharing of taxa between the Grassland and Succulent Karoo Biomes. Across South Africa, it has been found that numbers of alien and invasive species are significantly correlated with indigenous plant species richness (Richardson et al. 2005).

Using the biomes as defined in this book (but also extended to cover Namibia and Botswana), Chesselet et al. (2003) analysed the distribution of the 1 663 species of Mesembryanthemaceae, one of the most important families in our region. For the biomes compatible with our mapping area, by far the most species (871)

Biome	Albany Thicket	Desert	Forests	Fynbos	Grass-land	Indian Ocean Coastal Belt	Nama-Karoo	Savanna	Succu-lent Karoo
Desert	■								
Forests	649	■							
Fynbos	5 814	■	2 459						
Grassland	2 519	■	9 765	■					
Indian Ocean Coastal Belt	1	■	■*	■	■				
Nama-Karoo	2 993	361	■	448	9 600	■			
Savanna	2 070	■	7 045	273	18 807	3 737	6 560		
Succulent Karoo	1 555	513	■	8 949	■	■	2 354	■	
Northern border		507	25			27	239	3 004	
Ocean	403	12	76	1 442		879		3	455

Figure 3.4 Lengths (km) of shared boundaries between biomes. Black squares indicate no contact between biomes. *Forest patches touching or surrounded by Indian Ocean Coastal Belt were subsumed into the Indian Ocean Coastal Belt.

occur in the Succulent Karoo, a large number (382) in the Fynbos Biome with lower numbers in the Albany Thicket and Grassland Biomes. The IOCB harbours very few (8), but together with the other above-mentioned four biomes each has 75% or more (up to 93% for Fynbos Biome) endemic to the respective biome.

Comparisons of aspects relating to conservation status of biomes are found in Chapter 16.

1.6 Climatic Relations of Biomes

The general climate of each biome (i.e. averaged over the entire area of the biome and, therefore, representing only a central tendency for a biome) is summarised in the climate diagrams in Figure 3.6. Afrotemperate Forests and the area of IOCB experience the highest rainfall. The western parts of the Fynbos Biome and, in the drier areas, the Succulent Karoo Biome have a generally winter-rainfall regime. The Nama-Karoo experiences relatively low levels of rainfall that are concentrated in late summer and early autumn. The Grassland Biome is climatically similar to Savanna but with lower temperatures. The Albany Thicket has a greater and more pronounced bimodal (summer-autumn) rainfall than the Nama-Karoo. The coefficient of variation in annual precipitation is the lowest in the IOCB and the highest in the arid biomes such as the Succulent Karoo and Nama-Karoo Biomes. The number of frost days per year varies from zero in the IOCB to a maximum in the Grassland Biome. The mean annual potential evaporation is the lowest for the IOCB, with high values in the Nama-Karoo, Succulent Karoo and Savanna Biomes. Note how the IOCB occupies the lower extreme (i.e. moderate) for a number of key climatic variables.

Decision Trees have been used to classify biomes at continental scales (Lotsch 1999). Ellery et al. (1991) used a Decision Tree to present the biomes of Rutherford & Westfall (1986) climatically. Similarly, we derived a more specific and diagnostic climatic explanation of the current biomes from a Classification and Regression Tree using the CART method in S-Plus (univariate splits; Clark & Pregibon 1993 and discussion in Hargrove & Hoffman 2005; Figure 3.7). A simpler, more parsimonious, climatic explanation of the biomes was derived using a Hand Constructed Linear Decision Tree (see Murthy 1998) with multivariate splits but with slightly lower overall predictive accuracy (Figure 3.9). The climatic parameters used were deemed biologically meaningful and were: Mean minimum temperature of the coldest month (Tmin), heat units (HtUnt), annual mean evapo-

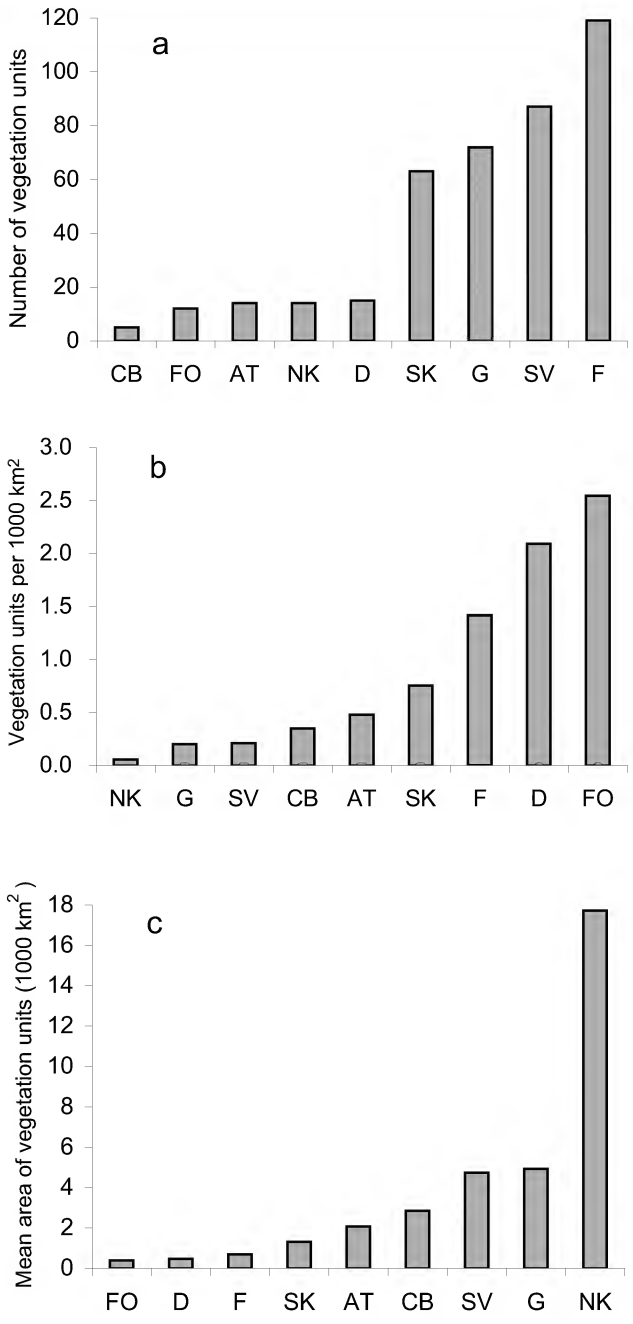


Figure 3.5 (a) Number of vegetation units per biome; (b) mean number of vegetation types per unit area within each biome; (c) mean area of vegetation units per biome. AT Albany Thicket, CB Indian Ocean Coastal Belt, D Desert, F Fynbos, FO Afrotemperate Forests, G Grassland, NK Nama-Karoo, SK Succulent Karoo, SV Savanna.

ration (Evap) and soil moisture days in winter (SMDW) and in summer (SMDS). Forests were not included in these analyses owing to their highly fragmented and widely dispersed nature.

Using the more parsimonious and, therefore, more coherent climatic description, IOCB is found mostly under conditions where soil moisture days are high in summer and relatively high in winter. Desert occurs mainly where soil moisture days both in summer and winter are low and evaporation is high. The Grassland climate differs from that of the IOCB by having a lower number of soil moisture days in winter (becoming lower with greater number of heat units) as well as a lower minimum temperature (dropping with increasing evaporation). Savanna climate differs from that of Grassland mainly in having higher minimum temperatures (level depending on evaporation) and a lower number of soil moisture days in winter (especially in areas of lower annual rainfall). Albany Thicket generally has a moderate number of soil moisture days in summer with moderate levels of evaporation as well as high minimum temperatures (declining with decreasing soil moisture days in winter). Fynbos and Succulent Karoo share some of the climatic attributes of Albany Thicket but differ from it in having lower minimum temperatures (and increasing with number of soil moisture days in winter). Fynbos has a greater number of soil moisture days in winter combined with a fewer number of heat units than in Succulent Karoo. The climatic derivation of Nama-Karoo is in two parts. The southwestern part of the Nama-Karoo has a relatively low number of soil moisture days in summer and moderate minimum temperatures. The northeastern part of the Nama-Karoo shares some of the climatic attributes of Savanna but differs from it in having lower minimum temperatures (declining in areas with higher evaporation).

CART performed between 0.2 and 9.8 percentage points better than the Hand Constructed Linear Decision Tree for seven of the biomes (Table 3.4). However, it was 16.2 and 17.1 percentage points worse for the Desert and IOCB, respectively. The linear extent of these two units was better reflected by the Hand Constructed Linear Decision Tree. Least adequately described climatically by both methods was the Albany Thicket Biome with less than 66% of its area predicted correctly. The biomes as mapped by CART are given in Figure 3.8 which also shows which areas (almost always on the margins) were incorrectly mapped. The correctly predicted areas from climate, therefore, reflect almost all of the core areas of the biomes and most of the error is limited to the transitional areas between biomes.

Climatic relations with biomes are rarely tested experimentally. In a limited study by Agenbach et al. (2004a), using reciprocal transplants of species across a boundary between the Fynbos and Succulent Karoo Biomes, it appeared that at least some Fynbos species were environmentally (including soils) limited, whereas at least some Karoo species may be limited in their distribution by fire and biotic interactions and not by their environment at this biome interface. It is thus clearly demonstrated, from local studies, that climate is not the sole determinant of vegetation distribution (Agenbach et al. 2004b). There may be boundaries between other biomes in the region which are not (only) determined by climate. The interface between our Savanna and Grassland Biomes may be one such possibility (Bond et al. 2003, 2005).

Threats of climatic change on a biome scale are usually discussed within each biome chapter, at least in terms of change in temperature and water availability. Possible effects of future levels of solar ultraviolet-B radiation on plants in South Africa are discussed by Musil et al. (1999). Those areas of South Africa with the highest current levels of UV-B radiation (Gariep Desert, Bushmanland and Kalahari Duneveld) should remain so but at even higher levels at around the middle of the 21st century.

1.7 Southern African Biomes in Context of Walter's Scheme

There are several global biome schemes available (see above for ample references), but an alternative one deserves particular attention not only because of its detail of elaboration (the actual map is accompanied by a series of monographs featuring the biome patterns in the light of ecophysiology and community ecology), but also due to its conceptual handling of zonality, intrazonality and azonality—one of the leading principles of the classification philosophy underlying our Map. It is the system

of zonobiomes of Heinrich Walter (Walter 1962, 1968, 1973, 1976, Walter & Box 1976, Walter & Breckle 1991, etc.).

Walter (for references see above) subdivided the terrestrial surface of the earth into nine zonobiomes, underpinned by the zonal character of climate (Table 3.5). Recognising the occurrence of broad transitions between these units, he further introduced the concept of zono-ecotones, calling them 'tension zones between two zonobiomes in which one vegetation type is being replaced by another…' (Walter & Box 1976).

According to the insert map in Walter & Box (1976) the territories of South Africa, Lesotho and Swaziland fall within four zonobiomes (II, III, IV and V) and two zono-ecotones (IV-III and III-II). The only direct match between our biome system and that of Walter is the identity of the Fynbos Biome and the zonobiome IV. Walter & Box (1976) classified the Fynbos Biome (explicitly) as one of the sub-zonobiomes of the global mediterranean biome (sometimes also called 'ethesial biome'). Our Succulent Karoo corresponds to zono-ecotone IV-III and partly to the zonobiome III, most probably through the 'sub-zonobiome with winter-rainfall' according to Walter & Box (1976). Walter's zonobiome III in southern Africa further covers the Desert Biome and western and central parts of the Nama-Karoo Biome. The eastern Nama-Karoo and Kalahari are classified by Walter as zono-ecotone III-II. The mapped extent of the zonobiome V in southern Africa is too generous as it comprises most of the southern Cape, Albany Thicket and the IOCB. The last-named should be best served as part of the zonobiome I (generally underestimated on the East African coast by Walter's classification), and the Albany Thicket as part of zono-ecotone I-III (as done for parts of Kenya/Somalia or Venezuela/Colombia). An interesting rare contact between two zonobiomes can be observed along the South Coast—meeting of the zonobiome IV (mainly linked to western oceanic coasts) with the zonobiome V (mainly linked to eastern oceanic coasts), forming a mosaic of the zono-ecotone V-IV (see also Walter & Box 1976). The extent of the zonobiome II (seasonal tropics), as mapped by Walter in southern Africa to encompass all of our Savanna Biome (except for Kalahari) and the Highveld plateau and the Drakensberg Mountain ranges, is also in need of modification—the primary temperate grasslands of our Grassland Biome should rather be re-classified as zono-ecotone II-VII or perhaps zonobiome VII (in the same way as the South American pampas).

2. Bioregions

A bioregion is a composite spatial terrestrial unit defined on the basis of similar biotic and physical features and processes at the regional scale. In this work, the intermediate level of vegetation organisation between that of vegetation type and biome, is the bioregion level.

The term 'bioregion' has been used less frequently than ecoregion (see below) and in very different ways, also globally. In South Africa, Rowe-Rowe & Taylor (1996) used the term bioregion for nine regions in KwaZulu-Natal, seven based on the original bioclimatic regions of Phillips (1973), with the remaining two bioregions deduced from Acocks (1975) and Camp (1995). The resultant units are generally at a level between our vegetation units and our bioregions for the province. The bioregions of Rowe-Rowe & Taylor (1996) have also been used by others (e.g. Avery et al. 2002). In a very different sense, Laurie & Silander (2002) use the term bioregion to equate to the large Cape Floristic Region. In Australia, the term bioregion has been used with the next more detailed level termed 'sub-bioregion' (Pullar et al. 2004) which, judging by the scale of these 'sub-bioregion' units, may approximate the level of our vegetation units. As has been pointed out in Section 1.3, the 'bioregions' of Burgess et al. (2004) are used at a hierarchical level even higher than that of our biomes. We do not refer further to their 'bioregions' here. It is clear that the term 'bioregion' has been used very loosely in the past. We hope that the current treatment will go some way to stabilising the usage of the term and concept.

Although our bioregions (Figure 3.10) represent a level intermediate between biome and vegetation unit, the IOCB is not divided into bioregions within South Africa but can be regarded as approxi-

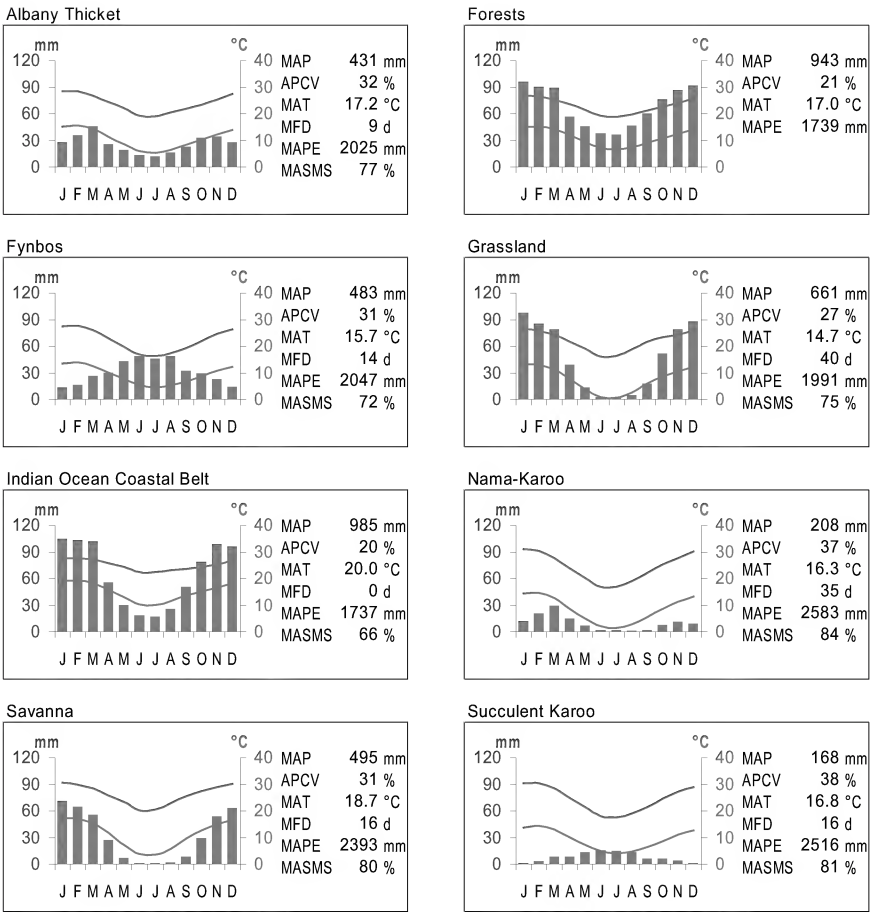


Figure 3.6 Climate diagrams of biomes excluding Desert. Blue bars show the median monthly precipitation. The upper and lower red lines show the mean daily maximum and minimum temperature, respectively. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days (days when screen temperature was below 0°C); MAPE: Mean Annual Potential Evaporation; MASMS: Mean Annual Soil Moisture Stress (% of days when evaporative demand was more than double the soil moisture supply). Note that the diagram for Forests represents the average of a wide range of rainfall seasonality.

Table 3.5 The scheme of Walter's zonobiomes (after Walter 1976, Walter & Box 1976, Walter & Breckle 1991, Box 2002). Simplified names for the zonobiomes were introduced.

Zono-biome	Name	Characteristics	Zonal Vegetation
I	Equatorial	▪ diurnal climate (mean of daily temperature amplitudes is bigger than the difference between the means for temperatures of the warmest and coldest months) ▪ rainfall usually high (above 100 mm per month), mainly aequinoctiale maxima ▪ zone between approx. 10° N and 5–10° S	▪ Tropical rain forest
II	Tropical	▪ clear colder and warmer period ▪ strong summer rainfall and extreme drought during colder period of the year (the drought period becomes longer and precipitation lower with increase of distance from the equator); fire-prone	▪ Tropical and subtropical savannas ▪ Seasonal tropical forests
III	Arid-Subtropical	▪ desert climate: very low precipitation—usually below 200 mm, in extreme desert below 50 mm; high insolation and light reflection; extreme daily temperature amplitude	▪ Deserts ▪ Semidesert shrublands
IV	Mediterranean	▪ winter rain and summer drought; usually on west oceanic coasts, between 35° and 40° in both hemispheres; fire-prone	▪ Evergreen microphyllous shrublands ▪ Seasonal evergreen forests
V	Warm-Temperate	▪ without pronounced cold winter period; ample year-round precipitation, especially high in summer; usually maritime climate due to prevailing location on eastern seaboards	▪ Evergreen broad-leaved forests
VI	Typical Temperate	▪ short cold (often with snow) period in winter (often lacking in oceanic regions) and warm summers; sufficient cyclonal precipitation	▪ Deciduous broad-leaved forests
VII	Arid-Temperate	▪ Extreme temperature differences between summer and winter due to continental position; usually low precipitation (bordering on desert climate); some ecosystems fire-prone	▪ Climatic grasslands (steppe, prairie, pampas) ▪ High-altitude semidesert shrublands
VIII	Cold-Temperate	▪ Cool and wet summers and very cold winters lasting sometimes more than half of the year; absent in southern hemisphere; fire-prone	▪ Boreal conifer forests (taiga)
IX	Arctic-Antarctic	▪ Cold and wet summers and extremely cold winters; evenly distributed precipitation over year; very short vegetation season	▪ Dwarf arctic shrublands (tundra) ▪ Polar deserts

mating a bioregion of the much larger belt that extends northwards into East Africa. The Albany Thicket Biome is not easily divided into bioregions and in effect has some properties that agree with those of the bioregion level. These two areas have, therefore, been included in some of the comparisons below. Afrotemperate Forests were not included owing to their highly fragmented and widely dispersed nature relative to the scale of the bioregion.

Table 3.4 Proportion of each biome correctly predicted (%) by the climatic models using a Hand Constructed Linear Decision Tree (HCLDT) with multivariate splits and a Classification and Regression Tree using the CART method in S-Plus (univariate splits).

Biome	HCLDT	CART
Albany Thicket	63.2	65.1
Desert	86.6	70.4
Fynbos	70.4	80.2
Grassland	77.0	85.1
Indian Ocean Coastal Belt	91.8	74.7
Nama-Karoo	85.6	85.8
Savanna	79.9	86.7
Succulent Karoo	66.7	74.8

2.1 *Bioregional Correspondence*

There is generally a very poor correspondence of the 16 'subdivisions of biomes' of Westfall & Van Staden (1996) with our bioregions. They simply used mean annual precipitation to subdivide the biomes of Rutherford & Westfall (1994). Our bioregions also differ in many respects from the phytochorial subdivisions of southern Africa where the highest level phytochorion is subdivided first into regions and more finely into domains (Werger 1978).

The *bioregion* also differs from the *ecoregion*. However, since the term ecoregion was coined in 1967 (Omernik 1987), it has been used very differently by different sources, complicating the comparisons. Ecoregions, through their availability, have been widely applied for a diversity of purposes (e.g. for units for which plant species diversity could be determined; Kier et al. 2005). Ecoregions have also been used to spawn new units such as combining them with Plant Hardiness Zones to form Plant Adaptation Regions (Vogel et al. 2005).

Ecoregions have often been defined on the basis of a dissection of physical environmental space, i.e. the ecoregion boundaries

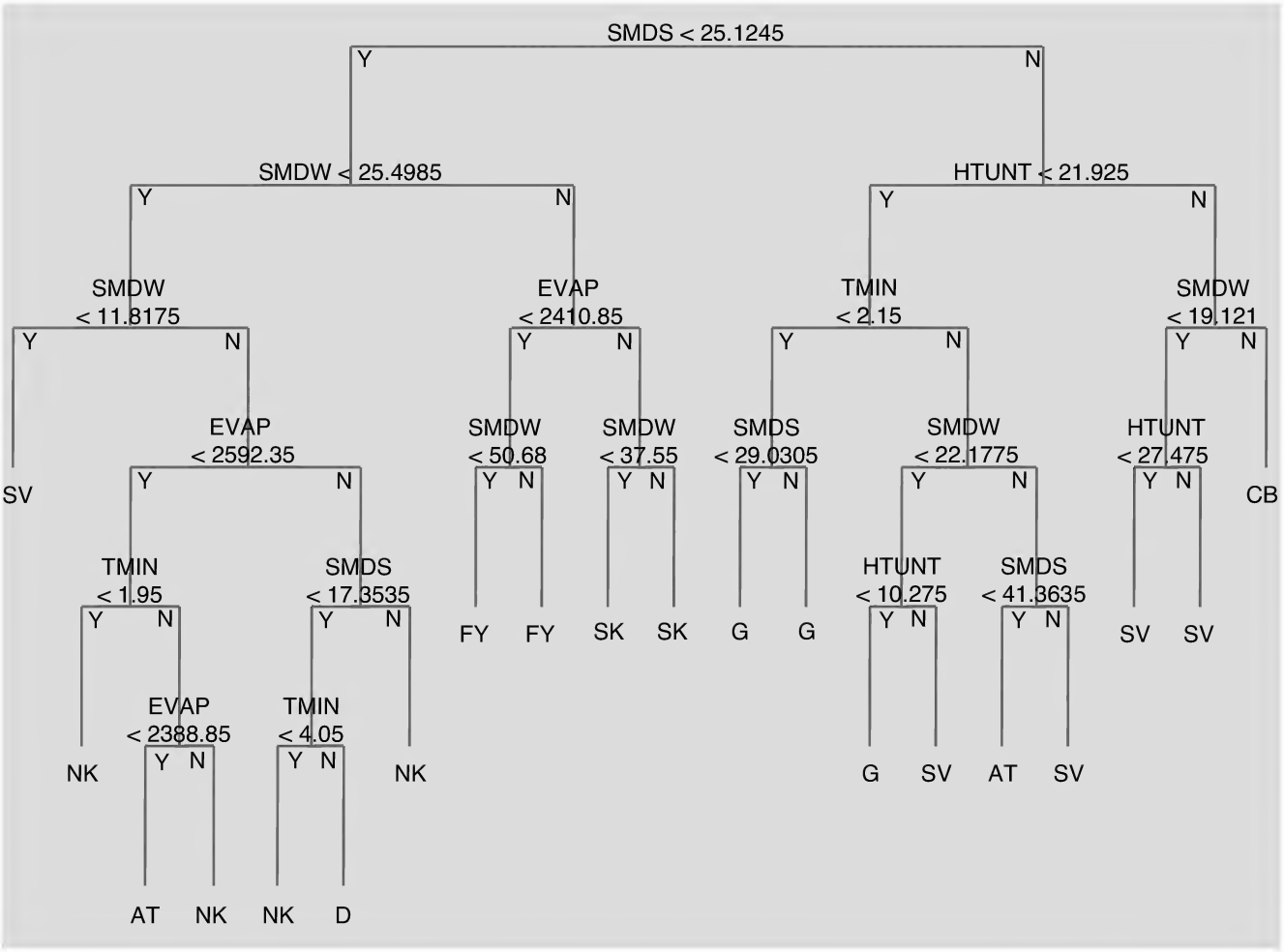


Figure 3.7 Computer printout of the climatic explanation of the biomes from a program for a Classification and Regression Tree using the CART method in S-Plus. TMIN: mean minimum temperature of the coldest month; HTUNT: heat units; EVAP: annual mean (potential) evaporation; SMDW: soil moisture days in winter; SMDS: soil moisture days in summer. AT Albany Thicket, CB Indian Ocean Coastal Belt, D Desert, FY Fynbos, G Grassland, NK Nama-Karoo, SK Succulent Karoo, SV Savanna. Y meets condition, N does not meet condition.

are primarily determined by climate (which 'solves the problem with using other components that are subject to rapid change, such as biota'—Bailey 2004). Ecoregions are sometimes also used at multiple hierarchical levels—e.g. in Australia (Pullar et al. 2004) and in the USA with four levels of ecoregion from the broadest level (Level I) to detailed Level IV (Omernik 2004).

More coherent and biotically inclusive are the ecoregions of Olson et al. (2001) although even within this same lineage, the ecoregions have changed over time (e.g. from Olson & Dinerstein 1998 to Burgess et al. 2004). They have nevertheless attracted a strong following. They have also attracted some criticism e.g. as they have been applied in Indonesia (Jepson & Whittaker 2002).

Our concept of *bioregion* and that of *ecoregion* of Olson et al. (2001) are similar. Both stress that biota are centrally important including distinct assemblages of species. Both are pragmatic units for practical application of conservation and other measures.

However, our bioregions differ from these ecoregions within our mapping area in (1) mapping scale with more detailed units, (2) underpinning by another layer of more detailed sets of biotic assemblages, (3) greater consolidation and coherency of associated climate (in some cases), (4) possible bias toward vegetation and, (5) we believe, more consistent geographical application of the concept. These differences are elaborated below.

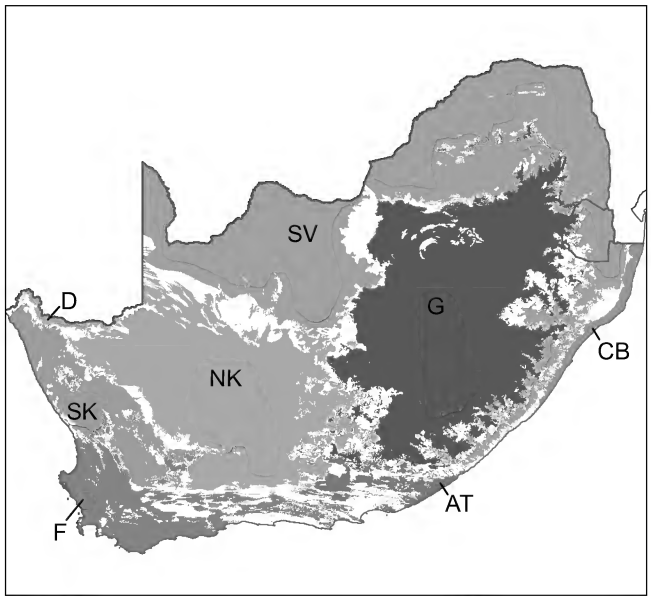


Figure 3.8 Map of the biomes as predicted by the Classification and Regression Tree using the CART method in S-Plus. Areas in white within our domain represent areas of error. AT Albany Thicket, CB Indian Ocean Coastal Belt, D Desert, F Fynbos, G Grassland, NK Nama-Karoo, SK Succulent Karoo, SV Savanna.

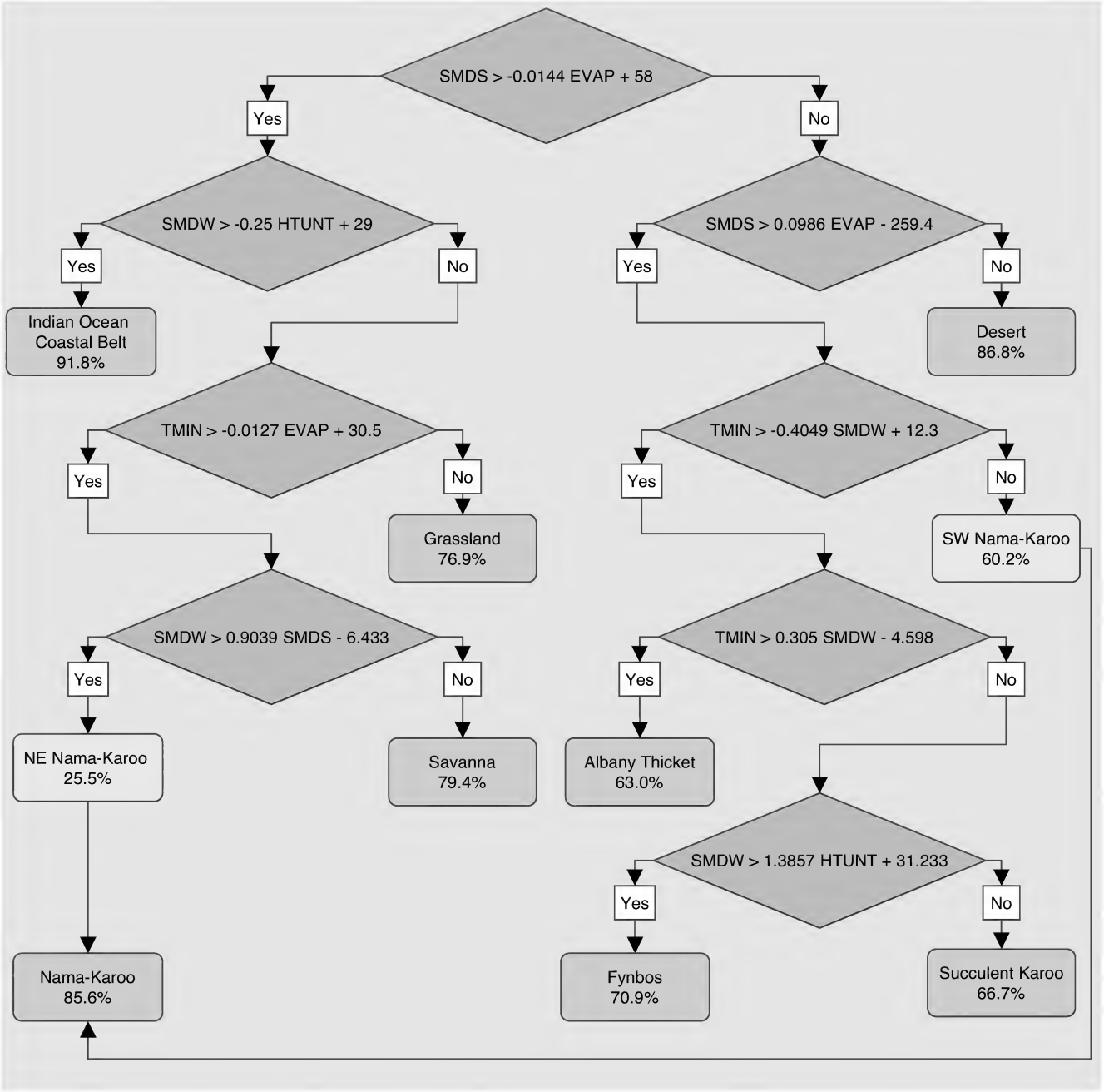


Figure 3.9 Climatic explanation of the biomes using a Hand Constructed Linear Decision Tree. TMIN: mean minimum temperature of the coldest month; HTUNT: heat units; EVAP: annual mean (potential) evaporation; SMDW: soil moisture days in winter; SMDS: soil moisture days in summer. Percentages are the proportion of the biome that was correctly predicted by the decision tree.

The average size of Olson et al.'s (2001) ecoregions globally is about 150 000 km^2 but is about 102 000 km^2 within our mapping area. Our bioregions are more finely divided with an average area of 54 000 km^2, i.e. roughly twice as detailed compared to the ecoregions.

In contrast to the ecoregions, the bioregions are underpinned by another level of biotic detail, namely vegetation types that make up each bioregion. There are on average over 10 vegetation types per bioregion, with the vegetation types (excluding azonal types) averaging just 3 100 km^2 in area.

Our bioregions follow a principle of regional consolidation, which recognises that a region should not consist of a widely dispersed array of areas and should rather be or tend towards being conterminous. In this sense it is similar in practice to one of the requirements for an ecoregion of Bailey (2004), namely to circumscribe contiguous areas. At the same time this was fitted to a coherent climatic profile for each bioregion. In this way we try to avoid recognising, for example, a 'Montane fynbos and renosterveld' Ecoregion (Burgess et al. 2004) which stretches as linear discontinuous bands from near Port Elizabeth in the east via the Cape Peninsula and the Roggeveld Escarpment to the Kamiesberg area in Namaqualand, and covers a wide range of climate. Climate tends to be more uniform within the more consolidated areas. Our principle of spatial consolidation for a bioregion also accepts that, despite distinct floristic differences between vegetation types in a bioregion, there are often also numerous species shared between adjacent vegetation types in a region.

Bioregions are focussed on plant diversity, i.e. on the floristic composition of their component vegetation types (and presum-

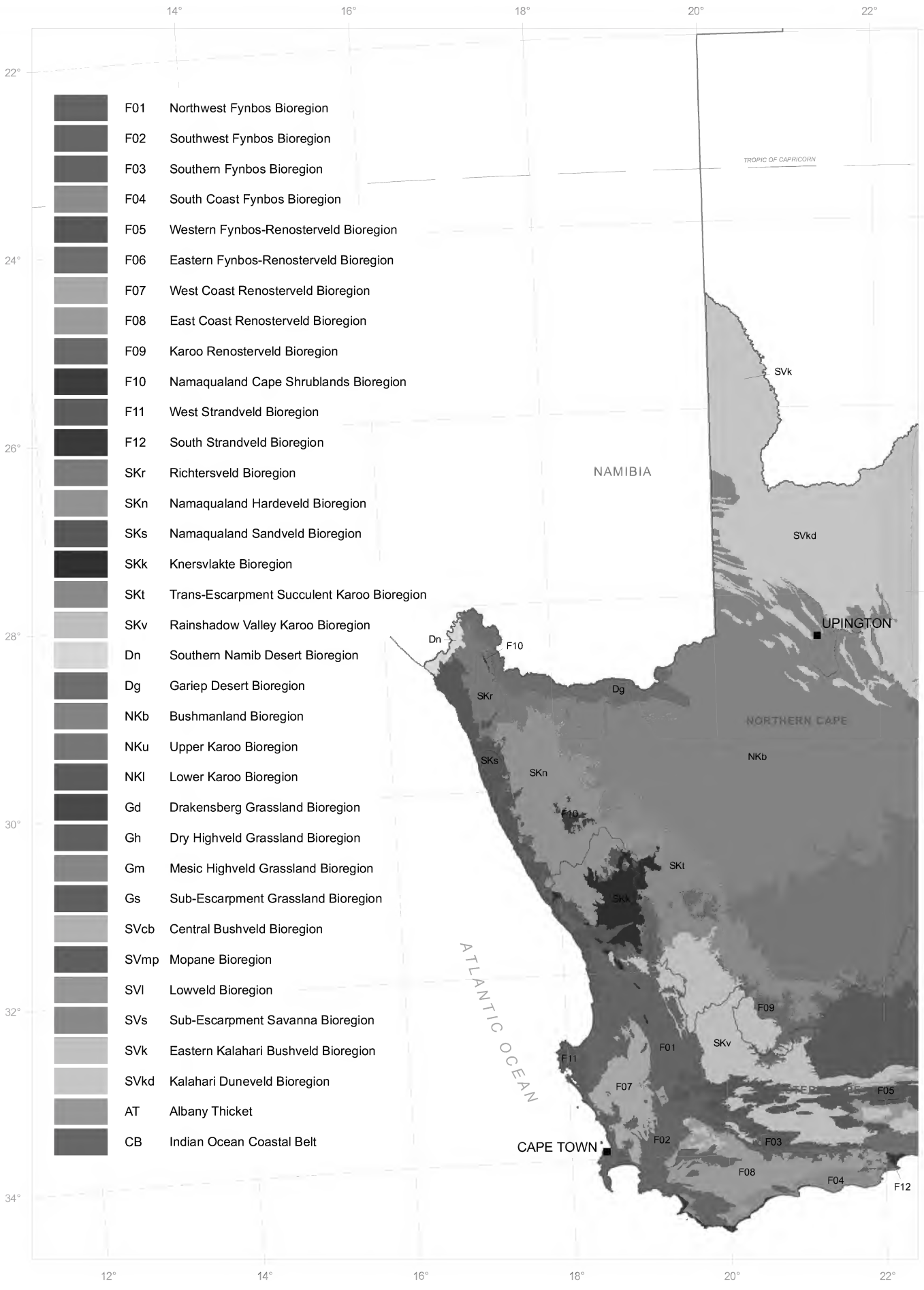
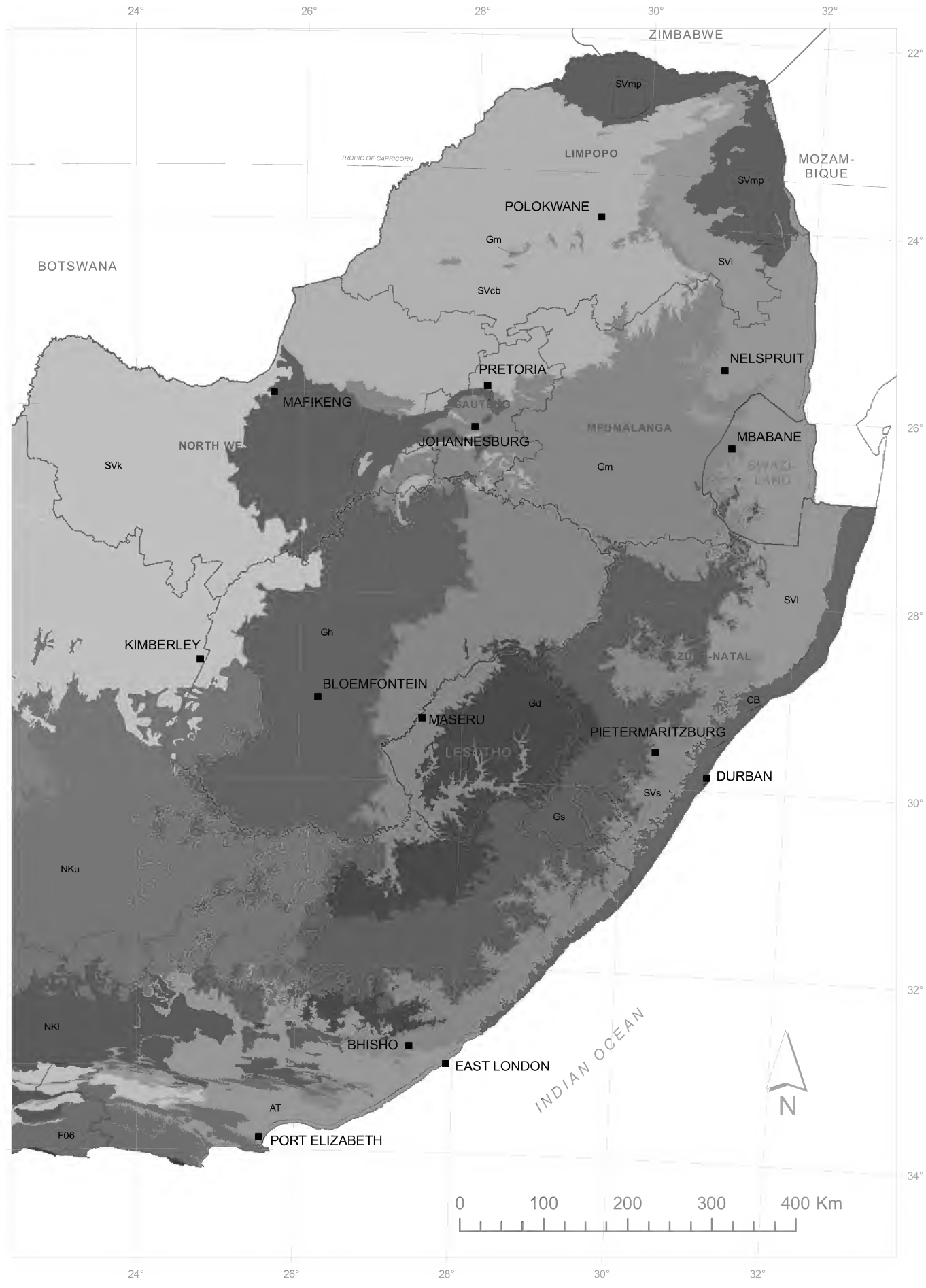


Figure 3.10 Bioregions of South Africa, Lesotho and Swaziland.


24°
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30°
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ZIMBABWE
SVmp
TROPIC OF CAPRICORN
LIMPOPO
MOZAM-
BIQUE
SVmp
POLOKWANE
Gm
SVl
BOTSWANA
SVcb
NELSPRUIT
PRETORIA
MAFIKENG
GAUTENG
MPUMALANGA
JOHANNESBURG
MBABANE
NORTH WE
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Gm
SWAZI-
LAND
SVl
Gh
KIMBERLEY
ZULU-NATAL
BLOEMFONTEIN
Gd
CB
MASERU
PIETERMARITZBURG
LESOTHO
DURBAN
SVs
Gs
NKu
NKl
BHISHO
EAST LONDON
INDIAN OCEAN
AT
F06
PORT ELIZABETH
N
0
100
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300
400 Km

ably an approximate surrogate for animal diversity), whereas ecoregions purport to be based on plants and animals and the imprint of geological history (Olson et al. 2001). However, in mainland Africa, most of these terrestrial ecoregions were derived from the vegetation units of White (1983) with some subsequent further divisions (Burgess et al. 2004). And where widely accepted biogeographical maps were unavailable, ecoregions were delineated on the basis of land forms and vegetation (Olson et al. 2001). This supposed difference between bioregion and ecoregion in bias of the former towards plants might, therefore, turn out to be rather semantic. In the southern African context we would contend that the bioregions are better founded on floristic principles than a number of the ecoregions, although not denying the importance of some ecoregions and their informative descriptions, e.g. those ecoregions in the area corresponding to the Fynbos Biome.

The appropriateness and consistency of the geographical application of ecoregions and their affiliations within our mapping region are dealt with in the paragraphs below.

There is generally a poor correspondence between individual ecoregions and bioregions. The few exceptions include the 'Southern Africa bushveld' Ecoregion which corresponds fairly well to the Central Bushveld Bioregion (78%). There is also some correspondence between the 'Zambesian and mopane woodlands' Ecoregion and the Mopane Bioregion (60%). Otherwise, there is a close correspondence between the 'Kalahari Xeric savanna' Ecoregion and the combination of the Kalahari Duneveld and Eastern Kalahari Bushveld Bioregions (91%). These correspondences are limited to the area of our mapping domain and should the concepts tend to diverge north of this domain, the overall level of correspondence would drop, possibly to a level of poor correspondence.

Widely divergent climate can occur within a single ecoregion (Burgess et al. 2004). For example, included within the Drakensberg montane grasslands, woodlands and forests Ecoregion are both the very high-rainfall grasslands around the Drakensberg in KwaZulu-Natal and the arid grasslands on mountains around Graaff-Reinet in the Karoo. The latter arid grasslands have been more appropriately included in our Dry Highveld Grassland Bioregion. Climatic ranges within ecoregions and bioregions in general do, however, deserve further analysis.

As emerges from the above, the ecoregions of Burgess et al. (2004) for South Africa, Lesotho and Swaziland appear hierarchically diverse and can correspond at multiple levels, i.e. biome level (e.g. 'Succulent Karoo' Ecoregion and Succulent Karoo Biome), bioregion level (e.g. 'Southern Africa bushveld' Ecoregion and Central Bushveld Bioregion), and approximately at vegetation type level (i.e. 'Drakensberg alti-montane grasslands and woodlands' Ecoregion and 'Drakensberg Afroalpine Heathland vegetation type'). Through the current work we would advocate a firmly placed bioregion level which should remain hierarchically stable.

2.2 The Bioregions

The Savanna Biome (in our mapping area) contains six bioregions. The Central Bushveld Bioregion has the highest number of vegetation types and covers most of the high-lying plateau west of the main escarpment from the Magaliesberg in the south to the Soutpansberg in the north. The Mopane Bioregion has the smallest area of the bioregions in the Savanna Biome (Figure 3.11) and lies at relatively low altitude north of the Soutpansberg and on the northeastern flats of the Limpopo Province. The Lowveld Bioregion extends from the eastern foot of the Soutpansberg southwards along the base and lower slopes of the escarpment, through the lower parts of Swaziland to the low-lying parts of Zululand in KwaZulu-Natal. The Sub-Escarpment Savanna Bioregion occurs mainly inland of the IOCB extending farther inland up major river valleys. The Eastern Kalahari Bushveld Bioregion is the largest savanna bioregion and is on average at the highest altitude (Figure 3.12). It is roughly bounded by Mafikeng, Bloemhof, Kimberley, Groblershoop and Van Zylsrus. The Kalahari Duneveld Bioregion has the fewest number of vegetation units and is typically found in the region of parallel dunes mainly in the Gordonia District north of Upington. On structural grounds (derived from satellite imagery), the Kalahari Duneveld Bioregion is, unlike the remainder of the Savanna Biome, not supported as a 'woodland biome' (Fairbanks 2000: Figure 2) and was also rejected on structural grounds as Savanna Biome in Rutherford (1997).

There are four bioregions in the Grassland Biome. The Drakensberg Grassland Bioregion is the highest-lying bioregion in the whole of our mapping area and occurs on the Lesotho highlands and immediate surrounds in KwaZulu-Natal, stretching southwards along the high-lying area of the escarpment in the Eastern Cape Province to reach the Stormberg and Amathole Mountains. It is the grassland bioregion with the fewest number of vegetation types. The Dry Highveld Grassland Bioregion constitutes the western belt (Graaff-Reinet and Aliwal North to Mafikeng) of the biome, mainly with a MAP below 600 mm. The Mesic Highveld Grassland Bioregion is the largest and has the highest number of vegetation types. It is found mainly in the higher-precipitation parts of the highveld and extends northwards along the eastern escarpment. It includes bushveld summit grasslands. The Sub-Escarpment Grassland Bioregion occurs at relatively low altitude on the plains and foothills of the Drakensberg and eastern escarpment from around Volksrus in the north to the Queenstown area in the south.

The Nama-Karoo Biome contains three bioregions, with a relatively even spread of number of vegetation types between them. The Bushmanland Bioregion occurs from the northeastern part of the Namaqualand area in the west to around Prieska in the east and from around Upington in the north to the Brandvlei/Sak River vicinity in the south. The Upper Karoo Bioregion is the largest and highest-altitude bioregion. It ranges from the eastern Calvinia District in the west to Burgersdorp in the east and from around Douglas and Petrusburg in the north to the Great Escarpment in the south. The Lower Karoo Bioregion is the smallest and at the lowest altitude. It mainly occupies the basin between the Great Escarpment in the north and the Cape Fold Mountains in the south, excluding areas of the Albany Thicket in the eastern part of the basin.

Of the two bioregions of the Desert Biome, the smaller is the Southern Namib Desert which stretches as a relatively narrow band up the valley of the Orange River from its mouth at Alexander Bay to around Sendelingsdrif. The much larger Gariep Desert extends farther up the lower Orange River Valley at a higher altitude over rugged terrain to around Onseepkans. (See Section 2.3 of this chapter and Chapter 6 on Desert for biome level considerations of these two groupings.)

All the biome chapters following this chapter are arranged according to the bioregions as set out except for the Fynbos Biome. The text in Chapter 4 is therefore arranged rather according to substrate types, emphasising the edaphic dependences of many Fynbos types but not necessarily their climatic affiliations important in the Fynbos bioregions. The close proximity and interleaving of very different vegetation types in the Fynbos Biome posed a challenge for establishing its bioregions and in terms of our consolidation principle, we have combined

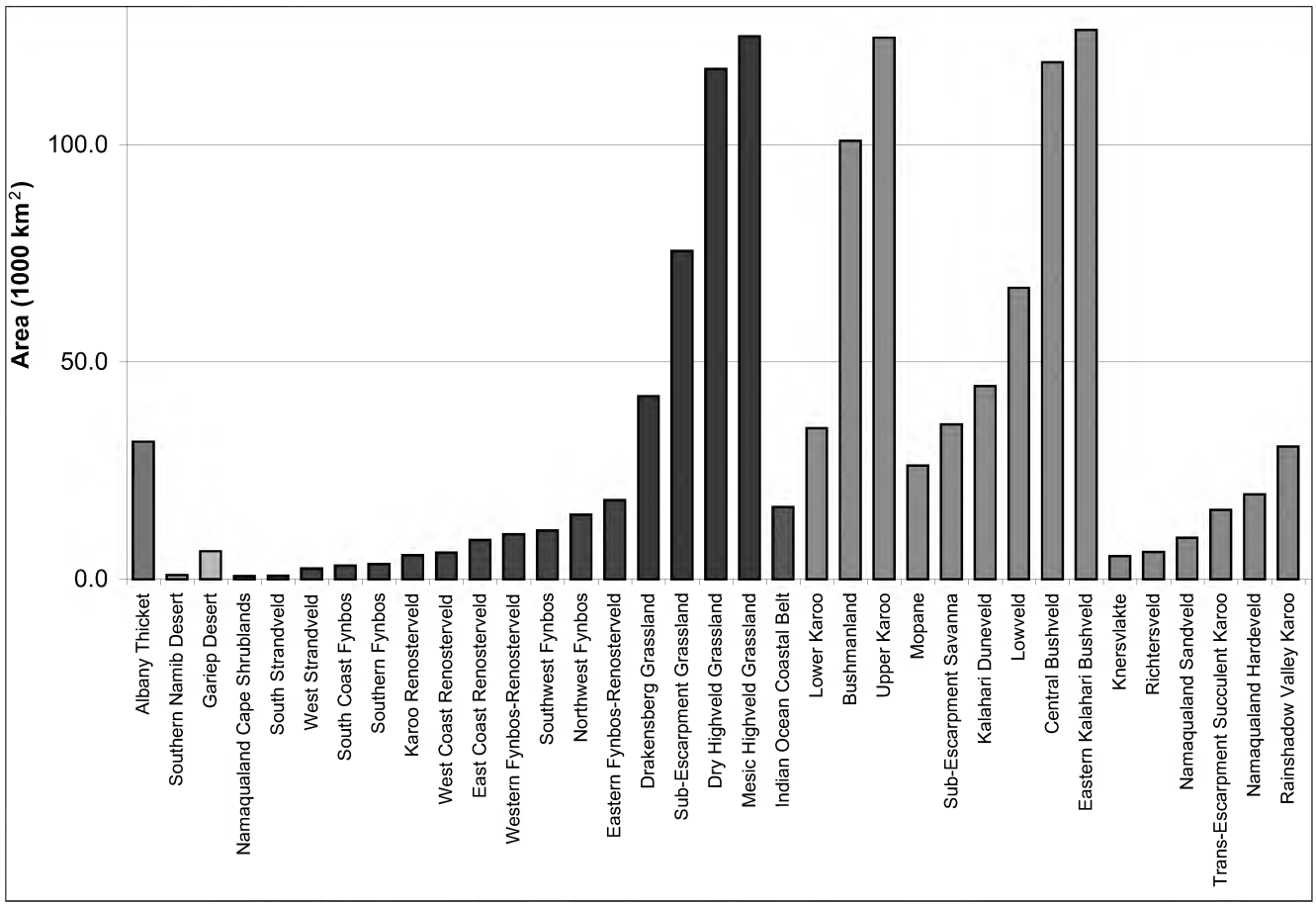


Figure 3.11 Areas of bioregions grouped according to biome.

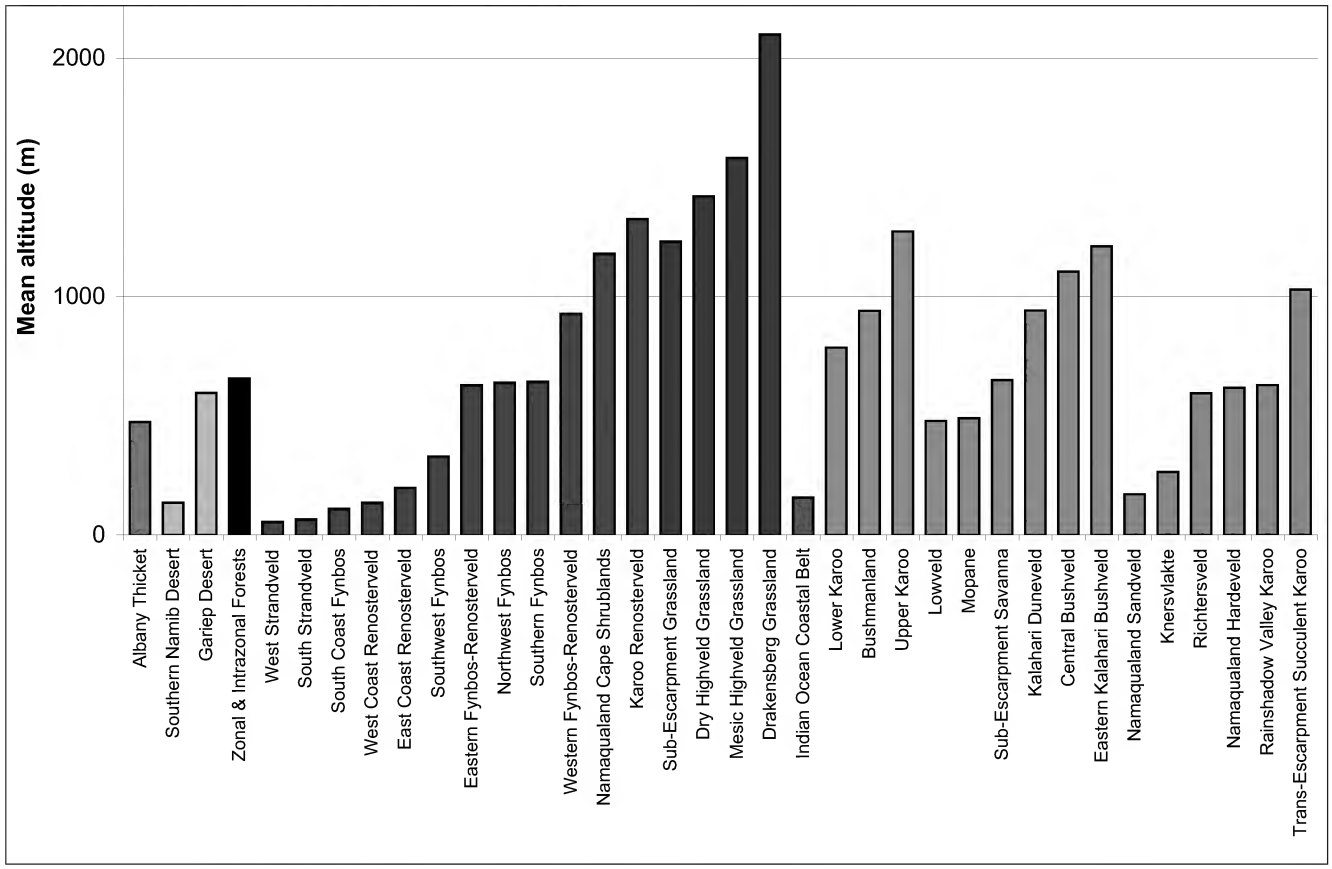
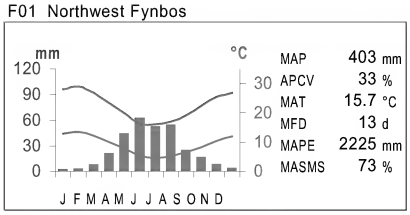
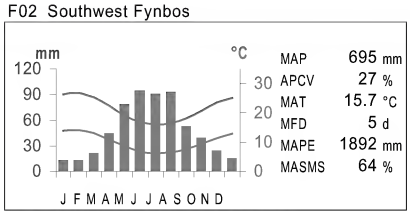


Figure 3.12 Mean altitude of bioregions grouped according to biome.

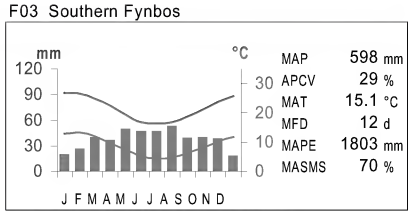
F01 Northwest Fynbos



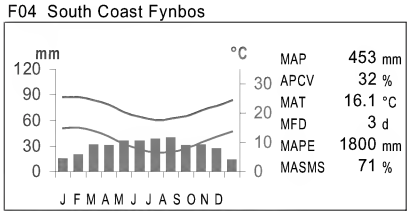
F02 Southwest Fynbos



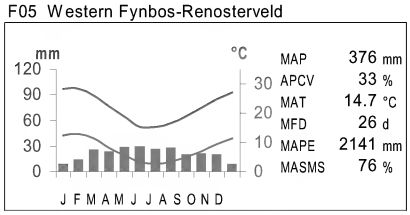
F03 Southern Fynbos



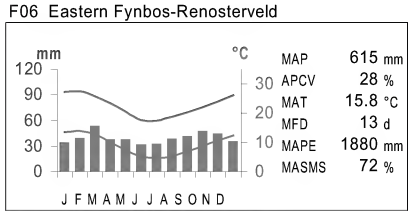
F04 South Coast Fynbos



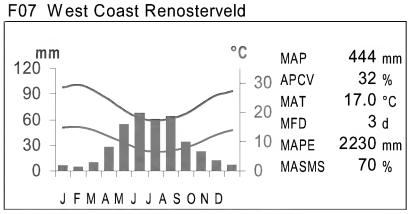
F05 Western Fynbos-Renosterveld



F06 Eastern Fynbos-Renosterveld



F07 West Coast Renosterveld



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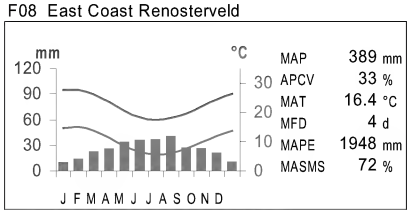
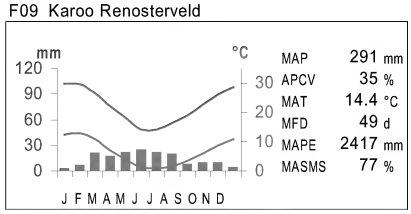


F09 Karoo Renosterveld



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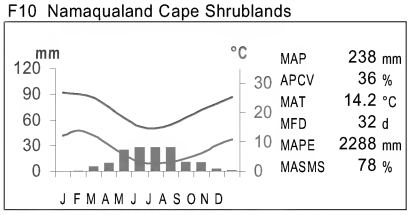
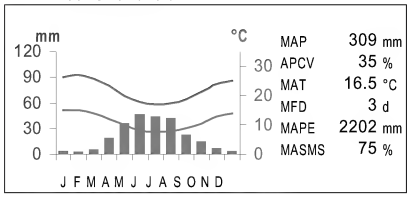
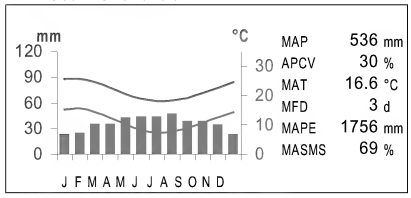


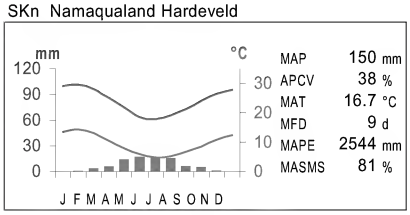
F11 West Strandveld



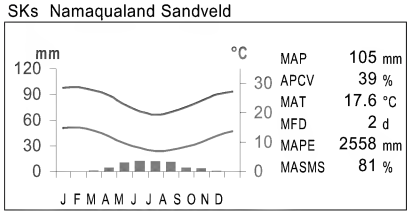
F12 South Strandveld



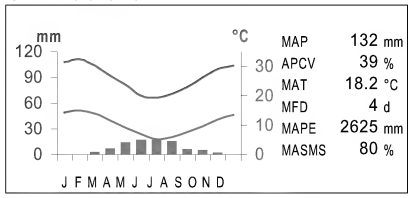
SKn Namaqualand Hardeveld



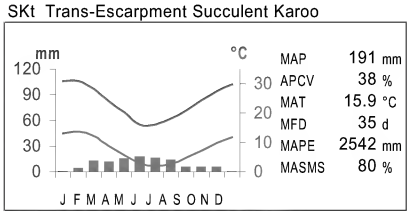
SKs Namaqualand Sandveld



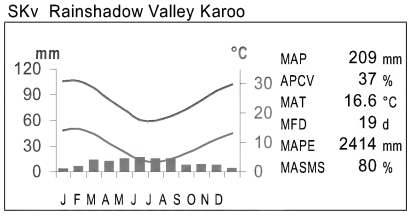
SKk Knersvlakte



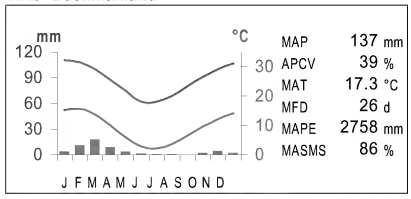
SKt Trans-Escarpment Succulent Karoo



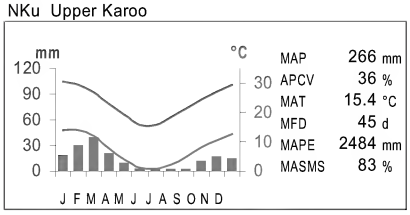
SKv Rainshadow Valley Karoo



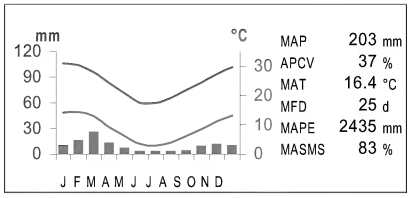
NKb Bushmanland



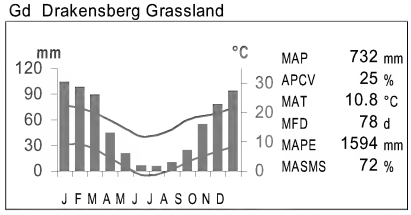
NKu Upper Karoo



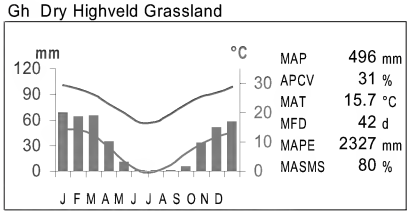
NKl Lower Karoo



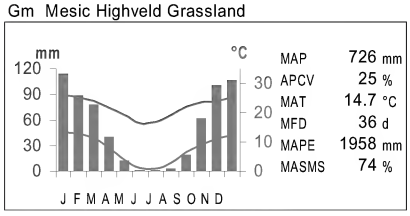
Gd Drakensberg Grassland



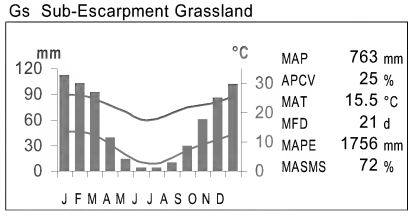
Gh Dry Highveld Grassland



Gm Mesic Highveld Grassland



Gs Sub-Escarpment Grassland



fynbos and renosterveld types in places (as have ecoregions of Burgess et al. (2004) within this biome). Thus the largest bioregion in the biome is the Eastern Fynbos-Renosterveld Bioregion which stretches from around George to Port Elizabeth and Grahamstown. To the northwest and west of this region is the Western Fynbos-Renosterveld Bioregion which mainly circumscribes the higher-elevation outcrops of fynbos in the Little Karoo from Uniondale in the east to the Touws River area in the west (except those associated with the Langeberg).

The floristic heartland of the Fynbos Biome is probably the Southwest Fynbos Bioregion. This is a sandstone (occasionally granite) and sand-defined unit and includes the mountains of the Kogelberg, Du Toitskloof area, Riviersonderend Mountains as well as the Cape Peninsula, Bredasdorp Mountains (including Potberg) and the fynbos of the sandveld on flats such as in the Hopefield District. This bioregion is flanked by two renosterveld bioregions. The West Coast Renosterveld Bioregion encompasses all the renosterveld areas to the west of the mountain chain from around Eendekuil/Piketberg in the north to Somerset West in the south. The East Coast Renosterveld Bioregion stretches from Bot River/Caledon in the west to the vicinity of Albertinia in the east and includes the renosterveld areas of the Breede River Valley. Positioned largely between the East Coast Renosterveld Bioregion and the ocean is the South Coast Fynbos Bioregion mainly on the flats between Bredasdorp and Mossel Bay. Immediately north of the East Coast Renosterveld Bioregion is the Southern Fynbos Bioregion which constitutes the sandstone mountain areas of the Langeberg from Worcester in the west to the vicinity of Herbertsdale in the east and includes higher sandstone outcrops in the Montagu area.

The second largest bioregion in the Fynbos Biome is the Northwest Fynbos Bioregion which covers the sandstone and sand areas of the biome from the Hex River Mountains in the south through the Cederberg to the Bokkeveld Escarpment near Nieuwoudtville in the north. Also included here is the Piketberg Mountain and sand patches north of Aurora on the flats to the Vredendal District and some patches northwards embedded in the Namaqualand Sandveld Bioregion of the Succulent Karoo Biome. Inland of these patches and at much higher altitudes is the smallest bioregion of the biome, namely the Namaqualand Cape Shrublands Bioregion. Most of this bioregion is centred in the Kamiesberg area of Namaqualand. The remaining two bioregions in the Fynbos Biome are strictly coastal and of very limited area. The larger unit is the West Strandveld Bioregion which is centred in the Saldana Bay area and extends northwards to Lambert's Bay and southwards to the Cape Flats bordering False Bay. The South Strandveld Bioregion occurs in patches from Walker Bay (Hermanus) in the west to the vicinity of Oyster Bay (near Port Elizabeth) in the east.

The Succulent Karoo Biome is made up of six bioregions. The Richtersveld Bioregion covers most of the hilly and mountainous Richtersveld except for the desert areas near the Orange River. It contains the largest number of vegetation types despite having the second smallest area. The Namaqualand Hardeveld Bioregion covers much of the higher-lying hilly area between Steinkopf in the north and Nuwerus in the south. To the west of this bioregion lies the Namaqualand Sandveld Bioregion, which is the lowest-lying bioregion occurring along the coastal plains from the Richtersveld in the north to the vicinity of the lower Olifants River in the south. The Knersvlakte Bioregion is the smallest bioregion and also lies at low altitude, but further inland than the last-mentioned. It is found mainly on the plains south of Kliprand in the north southwards to around Vanrhynsdorp. The Trans-Escarpment Succulent Karoo contains the fewest number of vegetation types and is the highest-lying bioregion, occurring on the upland plateau roughly from the Loeriesfontein area in the north to the vicinity of Sutherland in the south. The Rainshadow Valley Karoo Bioregion is the largest bioregion and includes the basins of the Tanqua, Robertson and Little Karoo as well as some areas north and east of the Swartberg.

2.3 *Climatic Relations of Bioregions*

Bioregions are divided into climatic entities with relatively similar climates within the bioregion and usually distinct climatic differences between bioregions. The following key climatic differences between the bioregions are identified.

In the Fynbos Biome, the Namaqualand Cape Shrublands Bioregion has the lowest MAP by a clear margin (Figure 3.13). The West Strandveld and Karoo Renosterveld have a similar, relatively low MAP but the former experiences almost no frost in contrast to the latter which has the highest incidence of frost in the biome. The Eastern Fynbos-Renosterveld Bioregion has the most evenly spread rainfall throughout the year. Less evenly spread rainfall is found in the Southern Fynbos, South

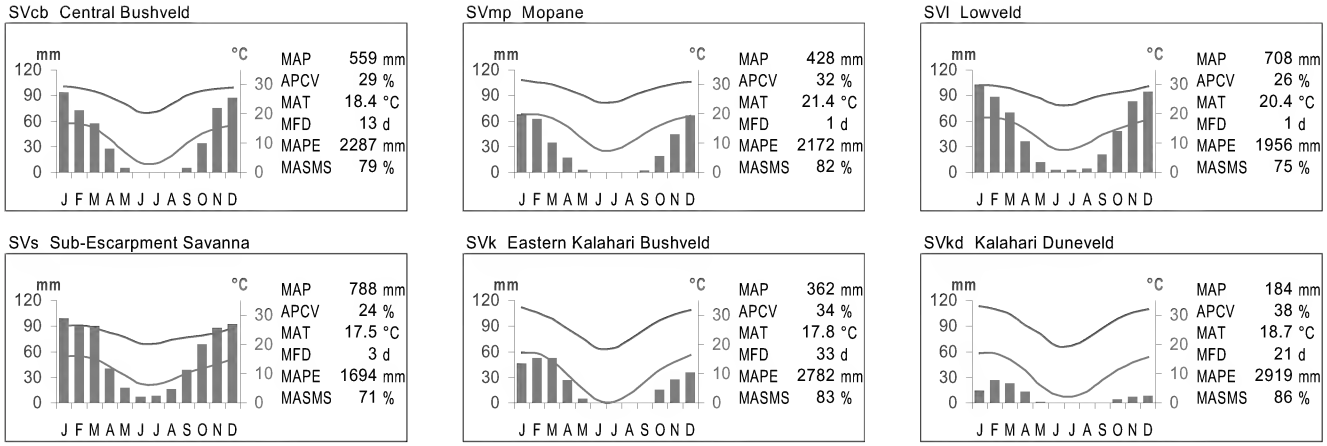


Figure 3.13 Climate diagrams of the bioregions grouped according to biome. Blue bars show the median monthly precipitation. The upper and lower red lines show the mean daily maximum and minimum temperature, respectively. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days (days when screen temperature was below 0°C); MAPE: Mean Annual Potential Evaporation; MASMS: Mean Annual Soil Moisture Stress (% of days when evaporative demand was more than double the soil moisture supply).

Strandveld and South Coast Fynbos Bioregions which have a decreasing MAP in the order given. The remaining five bioregions in the biome have a clear winter-rainfall pattern with low to very low rainfall in summer. Of these, the Southwest Fynbos Bioregion has the highest MAP followed by West Coast Renosterveld, East Coast Renosterveld and Western Fynbos-Renosterveld. The Northwest Fynbos is distinguished from these last-mentioned by its high annual potential evaporation.

In the Succulent Karoo Biome, the Namaqualand Sandveld has the lowest MAP, with the Rainshadow Valley Karoo and the Trans-Escarpment Succulent Karoo Bioregions having the highest MAP. The Trans-Escarpment Succulent Karoo has a much higher incidence of frost than the Rainshadow Valley Karoo. This incidence of frost approaches that of the adjacent Nama-Karoo Biome. The Namaqualand Hardeveld Bioregion has lower temperatures and more frost days than the Knersvlakte Bioregion. Climatic data for the Richtersveld Bioregion are too sparse to make specific comparisons with the other bioregions.

The Southern Namib Desert has a clear winter rainfall and relatively 'reliable' pattern of frequent fog in contrast to the Gariep Desert with precipitation ranging from even less predictable rainfall transitional between winter and summer to clearly summer-autumn rainfall; it experiences no fog. The effects of these climatic differences are so profound that these bioregions could probably each be raised to the level of biome. In the Nama-Karoo, the Bushmanland Bioregion has considerably lower MAP than the other two bioregions. Of the other bioregions, the Upper Karoo Bioregion has about twice as much frost as the Lower Karoo.

Within the Grassland Biome, the Drakensberg Grassland Bioregion has much lower temperatures, with a high incidence of frost compared to the other grassland bioregions. Dry Highveld Grassland has significantly lower precipitation than Mesic Highveld Grassland. Although MAP is similar between Mesic Highveld Grassland and Sub-Escarpment Grassland, the latter differs in its higher temperatures and fewer frost days.

In the Savanna Biome, the two bioregions with the highest MAP are the Sub-Escarpment Savanna and Lowveld, with the latter experiencing a significantly greater annual potential evaporation. The Kalahari Duneveld Bioregion has by far the lowest MAP in the biome. The Eastern Kalahari Bushveld Bioregion has more than twice as much frost as the Central Bushveld Bioregion while the Mopane Bioregion experiences virtually no frost.

It should be clear that the climatic relations indicated above represent climatic averages within a unit and, therefore, the overall trends and these averages do not address the spatial range of climate within a unit.

3. Credits

M.C. Rutherford wrote the text which was edited by L. Mucina who also added sections 1.1 and 1.7 which were in turn edited by M.C. Rutherford. L.W. Powrie was responsible for the technical compilation of the material for the figures and the tables (except for Table 3.5 supplied by L. Mucina). M.C. Rutherford and L.W. Powrie performed the decision tree analyses and W. Thuiller (now Grenoble, France) assisted with the CART decision tree. Data for the climate diagrams were taken or derived from the work of R.E. Schulze. This chapter is directed mainly at comparisons between biomes and between bioregions but we fully acknowledge the individual contributions to biome and bioregion boundaries supplied by the authors of the individual biome chapters in this book (see Credits at the end of each major chapter).

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Fynbos Biome

4

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1. Introduction: Concepts and Complexity Patterns

1.1 Scope of the Chapter

The primary aim of this chapter is to provide a description of the vegetation units as expressed on the Map (Mucina et al. 2005; see Chapter 18 entitled Vegetation Atlas in this book). Secondly, we attempt to discuss major features of the physical, geographical and evolutionary environment of the region housing the Fynbos Biome of South Africa.

The Fynbos Biome, due to its floristic, evolutionary and ecological peculiarities and conservation appeal, has experienced decades of intensive and dedicated botanical research (see Bond & Goldblatt 1984, Campbell 1985, Cowling 1992, Cowling & Richardson 1995, Cowling et al. 1997, Goldblatt & Manning 2000a and Van Wyk & Smith 2001 for comprehensive reviews as well as Boucher & McDonald 1982 and Boucher et al. 1995, 1996 for compilations of data sources). It may be argued that there is a renewed need to review our knowledge on the ecology of the Fynbos Biome since the last vegetation-focused review (Cowling et al. 1997) of almost a decade ago. Yet it is not our intention to provide still another, albeit possibly updated, review of the ecology of the Fynbos Biome. Our focus here is on the variability and typification of the vegetation of the Fynbos Biome in relation to geographical conditions, and the comparative ecological and evolutionary driving forces that shaped this unique and rich flora.

1.2 Concepts of the Fynbos Biome

The Fynbos Biome takes its name from fynbos—the dominant vegetation in the region. The concept of the biome is a unit defined on basis of climate, corresponding life-form patterns and major natural disturbances (Rutherford & Westfall 1994). Although well defined geographically, the Fynbos Biome strictly comprises three quite different, naturally fragmented vegetation types (fynbos, renosterveld and strandveld) that occur in the winter- and summer-rainfall areas, are dominated by small-leaved, evergreen shrubs and whose regeneration is intimately related to fire. It is one of two (with Albany Thicket) biomes endemic to South Africa. Although this biome concept is well understood, its fragmented nature is not convenient for inventory and regional analyses, and several additional concepts have arisen.

The earliest of these concepts was the 'Cape' as a region, as used by early explorers and botanists. The first concept of the fynbos flora in its modern position—as distinct from the inland Karoo—was that of Bolus (1886). Since then various studies dealing with the region as a phytochorion (a geographical unit based primarily on inventories and classification of species), have been undertaken (Taylor 1978, Cowling 1992). In its modern form, Taylor (1978) defined 'Capensis' and White (1983) the 'Cape regional centre of endemism' based on exceptional richness and high endemicity. Takhtajan (1986) regarded the area as a Cape Floral Kingdom (Capensis)—one of six floral kingdoms in the world. There have also been attempts at uniting the Succulent Karoo and Fynbos Biomes into a single winter-rainfall unit, based on the richness, endemism, the shared richness of the Aizoaceae and geophytes, and possible evolutionary drivers, but these are not relevant here.

However, many modern analyses, inventories and reviews use the concept of a Cape Floristic Region (CFR; e.g. Goldblatt & Manning 2000a). Unlike the above classifications, these include all the vegetation types (i.e. also Succulent Karoo, Albany Thicket and afrotemperate forests) within the area covered by the Fynbos Biome. This has been necessitated by the lack of data allowing species to be assigned to the different vegetation types (or biomes) within the region, and the need to conserve and manage the region as an entity. Furthermore, most of these omit the outlying areas of the Fynbos Biome north of Nieuwoudtville, east of Port Elizabeth and on the Great Escarpment. In this they approximate the area of the geological

Cape Fold Belt and effectively include the entire area underlain by the Cape Sequence geology and its basement rocks.

Most reviews summarise features across all these vegetation types, attributing much of the biodiversity and ecology to fynbos vegetation. It is true that almost all the endemic plant families, most of the spectacular floral diversity and endemism, occur in fynbos vegetation. Furthermore, in these attributes, fynbos vegetation so overwhelms the other vegetation types and biomes present in the CFR that it is tempting to ignore the 'lesser' elements. Indeed, among the tables, lists and literature, it is hard to extract information relevant to fynbos versus the other vegetation types or biomes. By contrast, the omission of the outlying areas underestimates endemism in fynbos taxa. For instance, endemism of species in the Proteaceae is 96.7% for the CFR, but 99.7% if the entire Fynbos Biome is considered.

To the general public, fynbos vegetation, Fynbos Biome, Cape Floristic Region, and Cape Floral Kingdom, are all synonymous, and the other local vegetation types and biomes are generally assumed to be a 'type' of fynbos. This is rendered even more confusing to nonbotanical lay people who mistakenly view 'fynbos' as a particular taxon or species.

In this book, we use the term 'fynbos' only for the vegetation type *sensu stricto*, and explicitly state when we are dealing with the biome or other classifications that incorporate the term.

1.3 Extent of the Fynbos Biome

The Fynbos Biome occupies most of the Cape Fold Belt (both north-south and east-west mountain chains and wetter valleys) as well as the adjacent lowlands between the mountains and the Atlantic Ocean in the west and south, and between the mountains and the Indian Ocean in the south. The northern boundary of the main biome area is delimited approximately by the Olifants River Valley north of Klawer and the Bokkeveld Plateau. However, a few patches extend as far north as Hondeklipbaai on the deep, red sands of the Namaqualand Sandveld, and there are also several patches at the highest altitudes (above approximately 1 100 m) of the Kamiesberg and Vandersterrberg in Namaqualand. The eastern borders of the Fynbos Biome are in the Albany region of the Eastern Cape, where grassy fynbos forms an intricate filigree with subtropical thicket units. The inland delimitation comprises relatively sharp boundaries with Succulent Karoo (see Chapter 18 in this book) approximating the Cape Fold Belt range, but outliers of the Roggeveld Escarpment tend to have broad ecotones. Within the biome, the Little Karoo and Robertson Karoo (supporting vegetation of the Succulent Karoo Biome) are large islands of arid bottomlands within the Cape Fold Belt.

Heathlands are not unique to the Fynbos Biome. Analogous evergreen, sclerophyllous shrublands extend as far as the Ethiopian highlands and even Madagascar, as ericaceous and proteaceous heathland and moorland. In South Africa these are found in patches from the Sneeuberg, Amathole and Drakensberg Mountains, with outliers in Korannaberg and near Nkandla, to the Northern Escarpment, Soutpansberg and Blouberg. Further north they occur at high altitudes in Chimanimani and Inyanga (Phipps & Goodier 1962, Van Wyk & Smith 2001) and East Africa (see Hedberg 1951). These heathlands and moorlands are now thought to be relicts of former wetter climatic periods and contain derived elements of Cape clades (e.g. *Ehrharta*: Verboom et al. 2003; *Protea*: Barraclough & Reeves 2005), rather than evidence of a northern origin for these elements.

1.4 Delimitation of the Fynbos Biome

The Fynbos Biome mainly borders the Succulent Karoo in the north and northeast and the Albany Thicket Biome in the east. The contact between the Fynbos Biome and Nama-Karoo is marginal (through FRs 3 and 5), as is the contact between the Fynbos Biome and Afrotemperate Forest Biome, especially its largest patch—the Knysna-Tsitsikamma forests. Only fynbos and renosterveld vegetation of the Fynbos Biome border on the neighbouring biomes, while strandveld is entirely contained within the Fynbos Biome and does not have any external boundary.

1.4.1 The Fynbos Biome/Afrotemperate Forest Boundary

Most of the fynbos—with the exception of the dry northern types and possible exception of dry asteraceous fynbos on sandstone and quartzite—is bioclimatically suitable for afrotemperate forest (Campbell 1985, Masson & Moll 1987, Manders 1990a, b, Manders & Richardson 1992, Manders et al. 1992). It is mainly the action of regular fire that excludes forest and allows fynbos to dominate the landscape (Figure 4.2). This is because trees are effectively excluded from fynbos by the slow growth rates due to the nutrient-poor soils and the relatively high fire-return intervals. Although most forest plant species are resprouters, they are unable to grow large enough to attain a tree form and reproduce before the next fire. In addition, seedling recruitment is of an inter-fire nature (not exclusively post-fire as is typical for fynbos) and appears to be tied to recycling nutrients within the litter layer, whereas in fynbos nutrients are volatilised or ashed by fire (Cowling & Holmes 1992b, Manders et al. 1992). Only one fynbos species regularly attains a tree form: *Protea nitida* (waboom), although trees exist among fire avoider species such as *Widdringtonia cederbergensis* and *W. schwarzii* in rocky outcrops, and *Leucadendron argenteum*

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Figure 4.2 Southern slopes of the Tsitsikamma Mountains (Groot River gorge north of Nature's Valley) recovering after a devastating fire. While the proteaceous and ericoid sandstone fynbos burned almost completely, patches of afrotemperate forest protected in deeper kloofs and in mesic subscarp positions were scorched only along the edges.

and species of *Virgilia* on the forest/fynbos interface. Even the waboom is confined to lower talus (richer) soils in fynbos and does not attain a tree form in denser vegetation or on poorer substrates. Other groups of trees found in communities of the Fynbos Biome are primary constituents of Cape thickets and riparian thickets well confined to fire-safe habitats (Campbell 1985). Forests are able to establish on richer soils, such as the shale bands of the Cedarberg Formation and shale soils, presumably because their faster growth allows them to establish a high fire-resistance together with low flammability of fuel (Cowling & Holmes 1992b).

Thus the 'true' (evergreen afrotemperate) forests are confined to large screes, deep kloofs and fire-safe zones protected by cliffs and scarps (see also Chapter 12 in this book). There is usually a sharp ecotone, often of the order of only metres in width, between fynbos and forest. The width of the boundary is determined by exposure to fire and the flammability of the vegetation in this zone. In the east, especially in the dissected coastal platform fire refugia driven by berg winds, the boundary is dominated by '*Virgilia divaricata* fynbos'. The fire-adapted shale-forest margin species (*Virgilia divaricata, V. oroboides*) should be considered a fynbos rather than forest element because of their fire-dominated recruitment dynamics and seed germination cues.

Renosterveld never adjoins afrotemperate forest as these habitats are too wet and support fynbos.

1.4.2 The Fynbos Biome/Succulent Karoo Biome Boundary

The interface between the Fynbos and the Succulent Karoo shrublands almost always occurs on sandstone and Tertiary sands in regions experiencing 200–300 mm of rainfall per year. Karoo replaces fynbos where the interplant spacing becomes too large to carry fire. This boundary is not only dynamic in terms of slope, relief, wind channels and fire-protected scarps, but also in that the two main plant protagonists can influence the boundary dynamics. Thus Restionaceae—the primary fire carriers in the fynbos—can carry hot fires into karroid areas, whereas, in the prolonged absence of fire, succulents may establish between the senescing fynbos plants and inhibit spread of fire (Cowling & Holmes 1992b).

It has been proposed that the boundary between Fynbos and Succulent Karoo is determined by the relative costs of evergreenness versus drought deciduousness and succulence, which is turn is determined by soil moisture (Miller 1982). In a review of this biome interface, Cowling et al. (1997) concluded that moisture availability rather than geology is the primary determinant of the Fynbos/Succulent Karoo boundary. In the Matjiesrivier Nature Reserve (MNR) of the eastern Cederberg the boundary can be predicted accurately based on geology and altitude alone: fynbos occurs on sandstone above 800 m (higher rainfall) and Succulent Karoo shrublands below 800 m (Lechmere-Oertel 1998, Lechmere-Oertel & Cowling 1999). In a small glasshouse experiment (Lechmere-Oertel 1998, Lechmere-Oertel & Cowling 2001) it was found that fynbos seedlings could not tolerate xeric conditions, whereas karoo shrub seedlings were able to grow successfully irrespective of moisture regime or soil type. Succulent Karoo vegetation therefore appears to be not limited by the environment, excluding the effects of fire, to the same extent as fynbos. Fire is very destructive in Succulent Karoo and prevents Succulent Karoo species from invading fynbos sites. However, karoo shrubs do not occur in fire-free fynbos habitats occupied by Cape thickets. Thus fire is excluded as an important factor and competition with fynbos excludes Karoo at the MNR. A small transplant experiment across the interface between Fynbos and Succulent Karoo on the Riviersonderend Mountains indicated that at least some karoo species may be limited in their distribution by fire and/or biotic interactions and not by the climate or geology. Here the boundary is determined by the fire-prone fynbos that is confined to sandstone (Agenbach et al. 2004; see also Chapter 3).

The Fynbos/Succulent Karoo boundary patterns are often complex in landscapes dominated by sandstone and quartzitic fynbos, where relief is a major indirect contributor to the boundary. But although the boundary may meander over the landscape, it is usually quite abrupt—in the order of metres. By contrast, in sand fynbos the boundary is often a broad zone of intermediate communities, dominated by *Willdenowia* or *Thamnochortus* stands that may extend over kilometres. Sharper boundaries occur in dune landscapes, but even gentle depressions, such as alongside river courses, can prevent fire and cause quite sharp transitions at a step in a slope.

In the northern extreme of FFd 1 Namaqualand Sand Fynbos, fynbos is not maintained by fire, but primarily by dune or other sand formations, and these communities extend to areas with rainfall below 200 mm rainfall per year on acid soils, presumably over shallow aquifers (A.G. Rebelo, personal observations).

Within fynbos, fire-free habitats may contain succulent vegetation rather than forest or Cape thickets, where the soils are skeletal such as on north-facing cliffs and extensive rock slabs (lithophytes), or in fire-safe enclaves within asteraceous fynbos. This interface is very poorly studied and it is not known whether the species in these patches are largely confined to fynbos or are merely islands of species common within Succulent Karoo vegetation. Some typical fynbos species (such as *Protea glabra*) are largely confined to these fire-free habitats.

Overgrazing, presumably by removing fuel, and thus influencing fire dynamics, can convert fynbos into a karoo shrubland, as observed at fence-line contrasts in the Kamiesberg (A.G. Rebelo, unpublished data).

There is very little area of contact between the Fynbos and the Nama-Karoo Biome (see Chapter 3). For the most part these biomes are separated by intervening areas of Succulent Karoo Biome or in the east by Albany Thicket.

Renosterveld occupies an intermediate zone on shale and alluvium between Fynbos and Succulent Karoo shrublands. The arid boundary between karoo and renosterveld has never been studied. Casual observations suggest that the boundary is plastic at between 250–300 mm, and that it is determined by the interplay between succulence and flammability of the vegetation. Therefore, like fynbos, the boundary between renosterveld and karoo is controlled by fire. This is supported by many apparently suitable habitats for renosterveld—such as southern slopes on small koppies, being karroid shrubland when they are too small or too isolated to carry fire (A.G. Rebelo, personal observations). Under exceptional conditions fire does penetrate well into neighbouring karoo shrublands, but this is rare.

1.4.3 The Fynbos Biome/Albany Thicket Biome Boundary

In regions with a considerable share of summer rainfall, Fynbos Biome communities often border on units of the Albany Thicket Biome. This can, for instance, be observed in the Little Karoo Basin, where AT 2 Gamka Thicket meets several arid fynbos units, in the Koega-Baviaanskloof-Grootrivier Mountains region where both AT 3 Groot Thicket and AT 4 Gamtoos Thicket are found bordering on grassy fynbos units. Further east, fynbos (notably FFq 6 Suurberg Quartzite Fynbos and FFh 10 Suurberg

Shale Fynbos) forms an intricate mosaic with core Albany Thicket units, dominated by either succulent shrubs or C_4 grasses (e.g. AT 9 Albany Coastal Belt and SVs 7 Bhisho Thornveld). Here grassy fynbos is replaced by grassland on drier, more inland, northern slopes, especially under lower-rainfall conditions. All factors describe lower moisture availability, suggesting that fynbos requires wetter conditions. This boundary, reflected by the increase in summer-growing C_4 grasses on the more fertile soils and summer-rainfall conditions, suggests that summer growth season temperature is the overriding factor (Cowling & Holmes 1992b). Southern slopes, with less of a summer growth season due to cooler, wetter conditions, may favour competitively superior Restionaceae, resulting in the formation of fynbos under wetter, coastal and higher-rainfall conditions. This would push the system from a near annual to a longer-rotation fire interval, allowing other fynbos species and communities to persist.

In the western part of the Fynbos/Albany Thicket contact (southern Cape and Little Karoo), experiencing a high share of winter rainfall, the border is determined by local geomorphology that controls runoff (soil moisture), exposure to desiccation (steep slopes) and fire movement. AT 1 Southern Cape Valley Thicket is limited to steep, highly exposed slopes and vertical cliffs in deep river canyons, characterised by skeletal, quickly desiccating soils and lack of fire. At AT 2 Gamka Thicket the boundary is determined by fire, although ultimately it is determined by moisture, except that the dynamics are governed more by the flammability of the constituent species as the vegetation does not become too sparse but too succulent to carry fire (Cowling & Holmes 1992b).

The boundary with the Albany Thicket vegetation units thus differs from that with the Succulent Karoo types in that at the Albany Thicket interface the role of fire is actively modified by the plant growth forms present. As a consequence, there is a marked area effect, not so readily observed at the Karoo interface. As most ignition events are caused by lightning, a certain minimum area is needed for fire to be frequent enough to maintain fynbos at the expense of encroaching thicket. Thus the occurrence of fynbos in the thicket-dominated landscapes is determined by the area of uninterrupted veld suitable for carrying regular fire. This produces characteristic patterns of fynbos extent on linear ranges (especially obvious in several quartzite fynbos types) that do not occur with Karoo. Where extensive areas of sandstone occur, fynbos dominates until aridity prevents fire from spreading, as in the case of Karoo. In many cases spekboom (*Portulacaria afra*) is the dominant plant on this margin.

It is not known if overgrazing, which preferentially removed succulent elements, might favour the encroachment of fynbos into thicket as might be expected—the reverse of the situation in the Karoo.

Renosterveld interfaces with the Albany Thicket Biome along the southern Cape coast, where AT 1 Southern Cape Valley Thicket is embedded within renosterveld units, in the Little Karoo Basin where AT 2 Gamka Thicket meets several renosterveld units, and where AT 3 Groot Thicket and AT 4 Gamtoos Thicket are found bordering on the renosterveld types east of Humansdorp.

On richer soils, renosterveld forms an intermediate zone between fynbos in the wetter areas and subtropical thicket on the arid interface. The boundary between the renosterveld/thicket contact is almost always determined by fire. Although thicket elements are prominent within renosterveld vegetation, the incidence of thicket stands within renosterveld becomes prominent east of Riversdale in FRs 14 Mossel Bay Shale Renosterveld, where the landscape is dissected and fire is unable to spread. Even in this vegetation type, thicket is largely confined to steeper slopes, gullies and outcrops, with renosterveld on the summits. Further east (east of the Kouga Mountains), renosterveld is confined to areas marginal to fynbos where fire is able to exclude thicket and maintain renosterveld. Where fire-prone fynbos does not occur adjacent to richer soils, renosterveld is unable to persist.

1.5 Global Position of the Fynbos Biome

The Fynbos Biome is a member of the global Mediterranean Biome, located on western shores of the continents of the world, at latitudes north (in the northern hemisphere) or south (in the southern hemisphere) of the arid (desert) belt associated with the horse latitudes around the Tropic of Cancer and the Tropic of Capricorn.

The global Mediterranean Biome consists of five geographically remote areas. In the southern hemisphere these areas include: (1) the Cape region housing the Fynbos Biome; (2) a small region in northern Chile, including the surrounds of Valparaiso and Santiago; (3) two separate regions in Australia, including the broad surrounds of Perth in southwestern Australia (also known as South-western Australian Botanical Province) and a smaller region in southeastern Australia (around Adelaide). The northern hemisphere portion includes: (4) the Mediterranean Basin along the coast of southern Europe, the Iberian Peninsula, North Africa, the Middle East, extensive regions in Iran, all Mediterranean islands and small outliers of the Canary Islands; and (5) the Californian Floristic Province (southwestern USA). All these regions are characterised by a mediterranean-type (warm-temperate) climate with warm, dry summers and cool, wet winters and support evergreen sclerophyllous shrublands as the dominant vegetation complex. In the Mediterranean, these are called *macchia* (*maquis*), *garrigue, phrygana, batha, matorral* and *tomillar*. In California they are called *chaparral*, while in Chile the local ecologists also use the Spanish term *matorral*. In Australia they are known as *kwongan* and *mallee*, while fynbos and renosterveld are well-established terms in South Africa (e.g. Di Castri & Mooney 1973, Di Castri et al. 1981, Specht & Moll 1983, Specht 1988, Cowling 1992, Arroyo et al. 1995b, Davis & Richardson 1995, Allen 1996, Cowling et al. 1996a, 1997, Rundel et al. 1998, Arianoutsou & Papanastasis 2004). Australia, South Africa and some regions of the Mediterranean have ecologically comparable nutrient-poor systems.

The flora of the regions have apparently very different evolutionary roots (Raven 1973, Axelrod 1975, Axelrod & Raven 1978, Raven & Axelrod 1978, Calsbeek et al. 2003, Linder 2003, Crisp et al. 2004), but a common set of ecological factors (predictable seasonal climate patterns and importance of fire) has produced a number of notable ecological convergences (Cowling et al. 1996a). The question of convergence (and nonconvergence) was the subject of a number of international meetings (Di Castri & Mooney 1973, Kruger et al. 1983), and subject to controversial discussions in the past and present (e.g. Schimper 1903, Specht 1969a, b, Parsons & Moldencke 1975, Cody & Mooney 1978, Cowling & Campbell 1980, Milewski & Bond 1982, Milewski 1983, Box 1987, Barbour & Minnich 1990, Herrera 1992, Cowling & Witkowski 1994, Arroyo et al. 1995a, Keeley & Bond 1997, Verdú et al. 2003, Cowling et al. 2005).

The mediterranean-climate regions cover less than 5% of the earth's surface, but contribute a disproportionably large number of species (about 20%) to the global flora of vascular plants (Cowling et al. 1996a). This floral richness as well as staggering local and regional endemism (for instance almost 70% in the

Fynbos) qualifies these regions as global hot spots (Mittermeier et al. 2000) and prime targets of conservation efforts.

2. Geography of the Fynbos Biome

2.1 Main Geological Patterns

The regions supporting the Fynbos Biome are a mosaic of various geological substrates—one of the major prerequisites for evolution of the remarkable diversity of taxa and vegetation types, making the Fynbos Biome one of the most fascinating botanical destinations. Sandstone, quartzite, granite, gneiss (marginally), shales and also young limestone sediments are the most prominent rocks of these regions (Figure 4.3).

Very prominent mountain chains mainly built of quartzite and sandstone peaks dominate the landscapes of the Fynbos Biome. These predominantly Cape Supergroup rocks are composed almost entirely of quartz and are thus extremely nutrient-poor. Locally, the Permo-Triassic mountain-building event that resulted in the folding of the Cape Supergroup varied greatly in intensity. For this reason, sandstones are found as flat-lying or gently dipping layers (e.g. Cape Peninsula and Cederberg) or as tightly folded, vertical and even overturned layers (e.g. the Langeberg and Swartberg ranges). Due to their extent and hard-wearing nature, these formations determine the morphology of the landscape in the Fynbos Biome.

The northernmost extent of the region of the Fynbos Biome is somewhat removed from the typical Cape Fold Belt-dominated geology of most of the biome. It is found in the Kamiesberg area, which has a basement of Mokolian gneisses formed during the Proterozoic. The Kamieskroon Gneiss and gneisses of the Stalhoek Complex as well as metasediments of the Bushmanland Group were metamorphosed during the Namaqua-Natal Orogeny to form this basement. These patterns as well as the Gariep Orogeny of the Namibian Erathem are discussed in Chapter 6 featuring South African deserts. The Gariep Orogeny was one of several Pan-African belts that resulted in the amalgamation of the Gondwana Supercontinent around 500 mya. In the Kamiesberg and the adjacent Knersvlakte, Vanrhynsdorp Group sediments overlie the older basement towards the southeast. These correlate with the Nama Group sediments, which were deposited in a basin adjacent to the Saldanian Orogeny, also of the Pan-African cycle.

The rocks of the Cape Supergroup have a Precambrian substratum that consists mostly of sedimentary rocks that were deformed and metamorphosed during mountain building in the Pan-African orogenic event. These include the metasedimentary Malmesbury Group of the southwestern Cape as well as the Kango Group of the southern Cape (which includes a considerable amount of limestone). These rocks formed in the oceans that surrounded the fragments of an earlier supercontinent, Rodinia, which rifted apart over 700 mya. These ocean basins were later to close again during the formation of Gondwana 500 mya, as continental plates were reorganised into this most recent supercontinent.

The orogenic activity that resulted from the convergence and eventual collision of the continents was accompanied by the intrusion of large plutons of granitic material into the Malmesbury metasediments. The granites and their host metasediments of this Saldanian Orogeny (as it is known in the southwestern and southern Cape) are exposed where the younger cover rocks have been eroded away. The rolling and often deeply weathered hills of the Swartland are composed of these metasediments. The granites around Saldanha, the Cape Peninsula, Paarl, Robertson and George are some of the more well known plutons of the Cape Granite Suite. These potassium-rich granites weather to form domes that are conspicuously different from the younger sandstone rocks that overlie them in many areas. Outcrops, such as at Lion's Head and Chapman's Peak on the Cape Peninsula, show that the granites and their host metasediments were exposed to erosion for a considerable period before the earliest Cape Supergroup sediments were deposited on top of them when sedimentation of these sandstones commenced in the Ordovician (see Compton 2004).

The Cape Supergroup has three important subdivisions, namely the Table Mountain, the Bokkeveld and the Witteberg Groups, and they remain remarkably distinct along the entire length of the Cape Fold Belt.

The older Table Mountain Group contains an extremely thick (1 550 m) package of rather homogenous quartzite known as the Peninsula Formation. Table Mountain, the type locality for this group, reveals most of the Peninsula Formation in a huge vertical section overlooking the city of Cape Town. These coarse sand packages formed in a high-energy environment (a wave-dominated delta) under the influence of a wet climate, with the result that the rocks are composed almost entirely of quartz grains. No other minerals less resistant to weathering survived the transport process. Terrestrial vegetation was still absent and thus erosion was much more pronounced in high-rainfall areas than it is today.

On top of the Peninsula Formation are the thin Cedarberg and Pakhuis Formations. These beds serve as fairly distinctive markers throughout the Cape Fold Belt, despite the fact that they are far more easily weathered than the quartzites above and below. They are distinctive because the vegetation that they host forms a green band that contrasts strongly to the bare outcrops of quartzite. The Cedarberg shale bands were formed in a deep-water environment of slow suspension settling of fine mud and organic material. The glaciogenic Pakhuis Formation was deposited on the Peninsula Formation and glacial pavements are still preserved at the top of these quartzites in some places.

The Nardouw Subgroup of the Table Mountain Group is another thick (500 m) package of quartzitic sandstone above the Cedarberg shales. It formed under similar conditions to the Peninsula Formation and is prominent above the Cedarberg shale bands today.

The Bokkeveld Group also consists of sandstones and shale, but differs from the Table Mountain Group in that the shale bands are much thicker and alternate with sandstone units. The greater proportion of shale leaves the Bokkeveld more susceptible to erosion and thus it commonly forms low-lying areas with low sandstone ridges. The area east of Caledon and north of Bredasdorp is fairly typical. Marine fossils, including trilobites and bivalves, are common in the lower part of this group of Devonian sediments.

Overlying the Bokkeveld is another more quartzite-rich Witteberg Group. These sediments were deposited towards the end of the Devonian and probably continued to be laid down during the Carboniferous. The central part of this group is mostly dominated by coarse clastic deposits including well-sorted sandstones, pebble-conglomerates and some siltstones. A prominent, light-coloured quartzite layer is distinctive in the Witteberg Mountains. Above and below this arenaceous (sandy) central part, the Witteberg Group are more argillaceous (shaly) sediments (Truswell 1970).

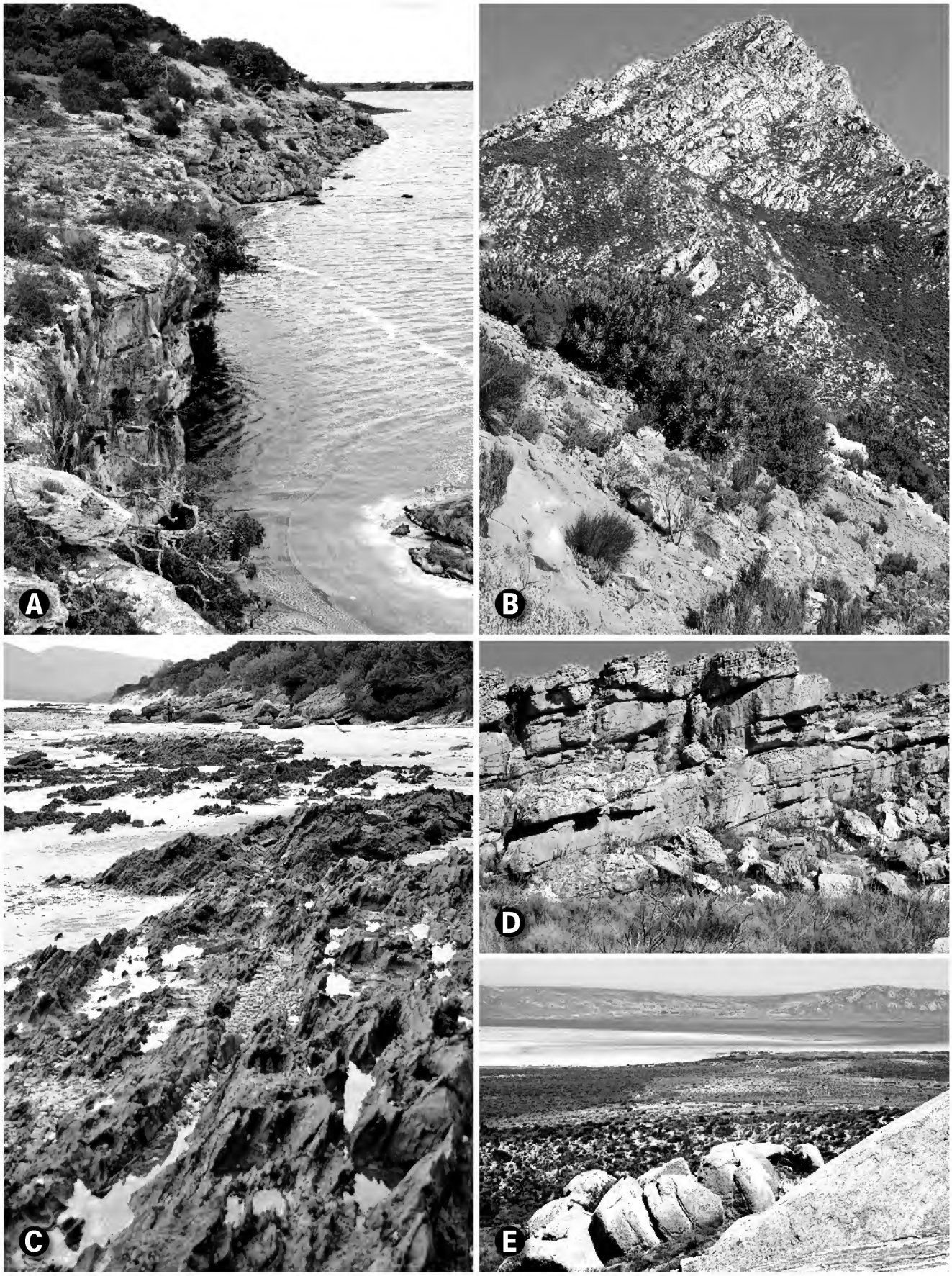

Figure 4.3 The geology of the Fynbos Biome is an important factor underlying the current diversity of the flora and the evolutionary diversification processes in the past. A: Tertiary limestone (De Hoop Vlei, Overberg); B: hard Ordovician Table Mountain Sandstone forms the dramatic peak and soft Cape Shale forms the shale band exposed by a road cutting (marine drive between Gordon's Bay and Rooiels); C: eroded Bokkeveld shales exposed on the seashore near the mouth of the Breede River (Witsand, Overberg); D: Nardouw sandstones of the Table Mountain Group (Op-die-Berg, Koue Bokkeveld); E: smooth topographic forms of a Cape Granite landscape (Langebaan Lagoon, West Coast). Photographs by L. Mucina.

Towards the end of Cape Supergroup sedimentation, Gondwana was taking up its position over the South Pole and the extensive glaciation that deposited the Dwyka Formation at the base of the Karoo Supergroup commenced. (The stratigraphy of the Karoo Basin is discussed in Chapter 8 on Grassland.)

The Cape Fold Belt is a remnant of the foreland fold and thrust belt of the Permo-Triassic Gondwanide Orogeny, formed when the Palaeo-Pacific Plate was subducted beneath southern Gondwana. Other fragments are preserved in South America, Antarctica and Australia (Trouw & De Wit 1999). Several phases of deformation in the Cape Fold Belt occurred from about 280 mya until around 220 mya (Hälbich et al. 1983).

The Cape Fold Belt has two branches that meet in the broad syntaxis domain that stretches from False Bay to Ceres and as far east as Montagu. In the western branch, which stretches to beyond Vanrhynsdorp, the large, gentle folds have a north-northwest strike and fade out towards the north and west. The southern branch has a distinct east-west orientation and experienced much more intense deformation. This branch is characterised by large, tight folds and overfolds as well as thrust faults. These structures verge towards the north and indicate a considerable crustal shortening in this area due to compression from the south (for further reading, see De Beer 1990). The Cape Fold Belt extends as far east as Port Alfred on the coast. Gondwana reconstructions show that the Falkland Islands were situated just to the east of this present-day coastline—they host the same sedimentary rocks.

During the Jurassic, Karoo sedimentation was brought to a close by the volcanic activity that formed the Drakensberg basalts. This period also saw the initiation of the rifting apart of Gondwana, which strongly influenced the geology of the south-western and southern parts of South Africa. The rifting event, which sculpted South Africa's coastline to its present form, also caused a horizontal extension that was manifested in large normal faults producing graben and half-graben structures.

The faulting produced marked changes in elevation that led to the rapid erosion of the high-lying areas. This produced the Enon conglomerates and the other clastic deposits of the Uitenhage Group that can be found in the Cretaceous sedimentary basins adjacent to the grabens. The faults displaced rocks vertically by several kilometres in some areas. The Worcester fault—with a 4–6 km displacement—is an example and red Enon conglomerates are spatially associated with it. Another example to the west of Port Elizabeth illustrates the juxtaposition of older, Namibian Erathem metasediments to the north of the fault, against (to the south) much younger Bokkeveld Group rocks that are partly covered by the Cretaceous erosion products. A similar outcrop pattern has developed near Oudtshoorn.

In the off-shore basins along the South Coast, the Cretaceous sediments host hydrocarbon reservoirs that are being exploited to a limited extent at present. These large, and numerous, faults are also responsible for preserving outcrops of Cape Supergroup quartzites as down-faulted blocks such as Table Mountain and the Cape Peninsula as well as Piketberg. This has preserved them from erosion, while adjacent higher-lying blocks have been eroded down to the pre-Cape basement.

In more recent times, rates of eustatic uplift together with global changes in sea level have influenced the erosion and sedimentation along the coastline as well as the incision of rivers into the Cape Fold Belt. Periods of high relative sea level have left recent deposits of sandstone and limestone on flat wave-cut platforms in many parts of the southwestern Cape. The Tertiary to Quaternary Bredasdorp and Strandveld Groups are examples. Times of low relative sea level have resulted in the down-cutting of rivers as is characteristic of the southern Cape, with streams occurring in deep incised valleys. Other evidence for this can be found on the off-shore Agulhas Bank across which former channels of the Gourits and Breede Rivers can be traced (Truswell 1970, p. 148).

2.2 *Landscape Evolution*

The West and South Coast lowlands, where most of the lowland renosterveld types are concentrated, have totally different erosion histories. While regions supporting West Coast renosterveld today have had kilometres of sediment removed since Gondwana started separating, erosion of the region of the South Coast renosterveld units has been relatively sedate.

The Witteberg quartzites, Bokkeveld shales and Table Mountain sandstones have been removed over the last 100 my on the West Coast, reducing the geology to the Malmesbury shales and Cape granites up to the Porterville fault. Only three inselbergs of sandstone (with Fynbos) remain on this plain—Piketberg, Riebeek-Kasteel and the Cape Peninsula. A few isolated pockets of silcrete and ferricrete remain, but they are not prominent. Adjacent to the Porterville fault, extensive alluvial fan deposits occur: these are typically covered with fynbos. The topography is relatively flat and low (80–200 m), although there are two elevated watersheds: (1) west of the Berg River comprising the granite hills of the Paarl Mountain, Paardeberg (with fynbos on the summits) and the shale hills of Kanonberg (370 m), Tontelberg (360 m) and Swartberg (480 m), and (2) the shale hills of Tygerberg (460 m), and the granite hills of the Bottelary Hills (480 m, mainly with fynbos), Dassenberg (570 m) and Darling Hills (450 m). North and east of the Berg River the only inselberg is Heuningberg (360 m, with fynbos on its northern end).

East of the Porterville fault, the Cape Group sandstones form a largely flat area—the Cederberg and Bokkeveld covered with fynbos vegetation types, with the exception of the Olifants River and Koue Bokkeveld synclines which are locally strongly down-curved bottomlands with young rocks. The area dips gently to the east, with younger sediments progressing eastwards: the Witteberg quartzites at Swartruggens, and finally the Karoo sediments in the Tanqua Karoo, where the Succulent Karoo Biome abuts the Fynbos Biome.

Over most of the South Coast and interior, only the Witteberg quartzites have been removed, so that the Bokkeveld shales form the bedrock, although in the eastern coastal part of the region even this has been removed. Shale renosterveld of the Rûens region—the largest continuous block of renosterveld—is characterised by undulated hills in the west and deeply dissected hills in the east, at a general elevation of 200–300 m. A single Witteberg quartzite inselberg remains at Riversdale. Extensive silcrete and ferricrete remain on higher areas, often forming flat-topped hills and scarps. Enon conglomerates form an apron along the Langeberg and Outeniqua Mountains—these usually support asteraceous and grassy fynbos, with limited patches of renosterveld. The southern margin adjacent to the coastal limestones is often covered with a thin layer of calcrete, but these areas have been transformed to cropland and their flora is largely unknown. During the Pleistocene glaciations, the Agulhas Plain extended 200 km south of its current range, a fair proportion of this would probably have been renosterveld.

Both the Langeberg and the Swartberg Mountains are major fault zones, the faults being several kilometres south of the current mountain scarp, exposing older rocks which are partly covered by Enon conglomerates deposited as the sandstone scarp

retreated. These contain mainly fynbos vegetation. Between the Langeberg and Swartberg ranges the rocks are gently folded, giving rise to gentle mountains with fynbos where the sandstone is exposed and valleys with younger sediments and predominantly karoo and renosterveld vegetation. North of the Swartberg range, the Bokkeveld and Witteberg rocks are narrow ranges, but in the western Karoo these are also gently folded, giving rise to parallel scarps of resistant quartzites, with the Witteberg being the northernmost of these before being replaced by younger karoo sediments. Inland renosterveld occurs predominantly on Bokkeveld shales and on Witteberg shales between the quartzite scarps and ridges. Topography varies from subdued in the west, to valley basins in the east and ridges and scarps in the north.

2.3 Soils of the Fynbos Biome

A wide range of environmental conditions, such as present and past rainfall, parent material, terrain type and the age of different landscapes, resulted in the very large variation in soil types and soil associations that are characteristic of the Fynbos Biome (Lambrechts 1983, Schloms et al. 1983, Lambrechts & Fry 1988). Various developmental soil form sequences or catenae, based on topographic position, age, clay and iron content, drainage and/or soil depth, can be constructed for different combinations of environmental conditions (see Figures 4.4–4.7). However, parent material (i.e. the underlying rock type) or the nature of recent deposits, is probably the primary factor determining the physical and chemical nature of the different soil types. In the following paragraphs the dominant soil types (soil forms) associated with different combinations of parent materials are featured and their link to vegetation is discussed. For detailed description of the soil forms defined in the text, refer to the Soil Classification Working Group (1991).

2.3.1 Heavy-textured Soils

Shales and slates of the Malmesbury Group of the southwestern Cape, Kango Group of the southern Cape (including considerable amount of limestones), and of the Bokkeveld Group are less resistant to weathering than quartzites and sandstones of the Cape Supergroup. Due to their mineral composition these rocks give rise to soils that differ considerably from the quartzite-derived soils. These soils are usually heavy-textured, with large fine-sand and silt fractions, and show a much higher nutrient status, especially potassium. Three soil regions (relict erosional plains, coastal foreland and valley zones) can be distinguished on the basis of combinations of environmental conditions (Figure 4.4).

Among the upland plains, the Koue Bokkeveld and Elgin Basin are prime examples of old Tertiary erosion surfaces underlain by Bokkeveld shales. The terrain is undulating, with small remnants of the old land surface. On these remnants, deep red (Hutton form) or yellow-brown (Clovelly and Oakleaf forms), highly weathered, clayey soils occur, with varying amounts of ferruginous gravels and/or laterite. These soils are generally porous, well-drained, highly leached and acid, and rich in kaolinitic clays. Similar soils occur on remnants of lower erosional surfaces (at altitudes of approximately 200–350 m) along the foothills of mountain ranges such as Simonsberg and the Drakenstein Mountains (Figure 4.4). Shale fynbos is associated with these soils.

On younger dissected slopes, moderately to deep yellow apedal soils (Pinedene and Tukulu forms) developed on slope-creep

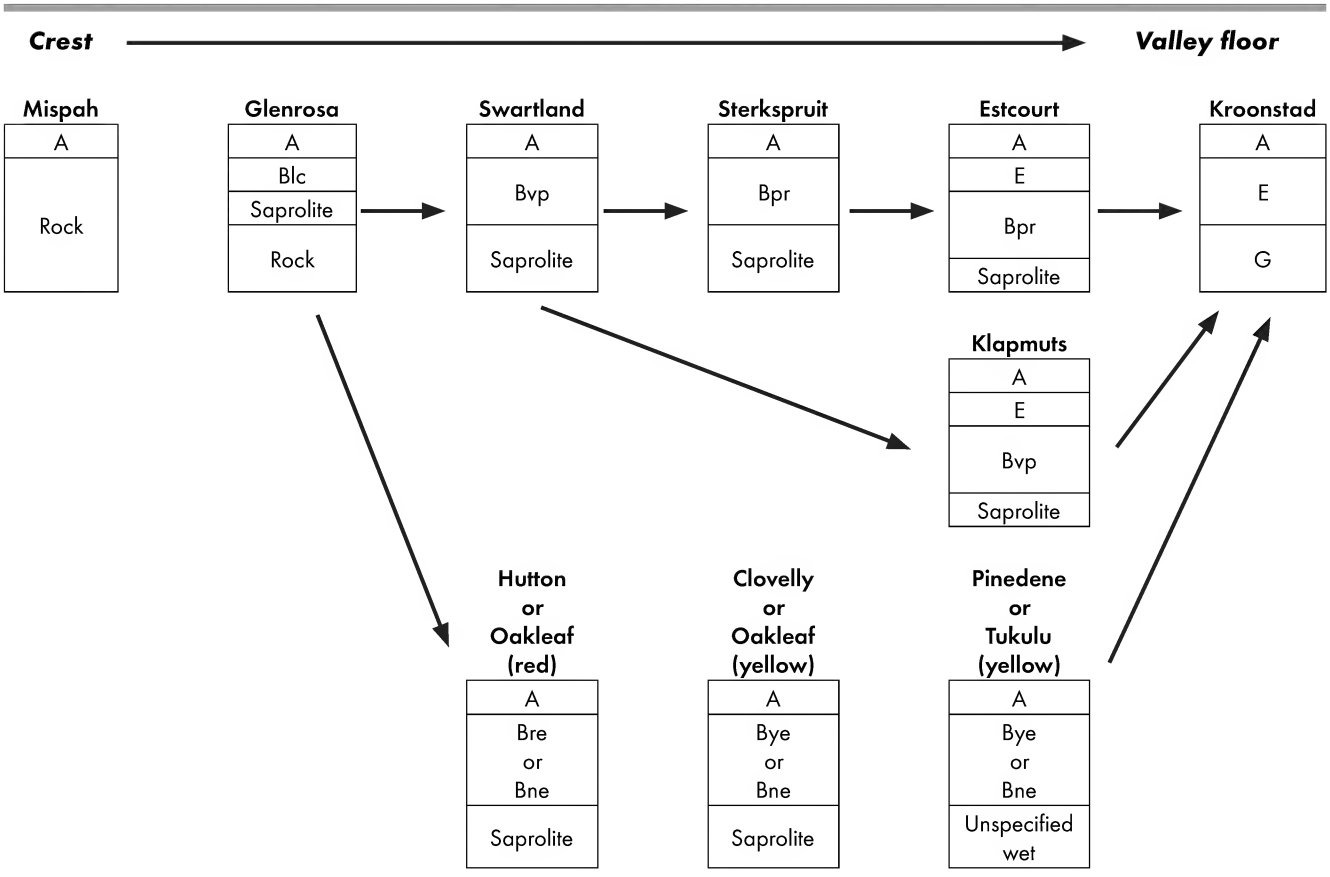

Figure 4.4 Heavy textured and duplex soils from shales, slates and granites. Abbreviations: A = orthic A-horizon; E = E-horizon; Blc = lithocutanic B-horizon; Bvp = pedocutanic B-horizon; Bpr = prismacutanic B-horizon; G = G-horizon; Bre = red apedal B-horizon; Bye = yellow-brown apedal B-horizon; Bnc = neocarbonate B-horizon.

materials from the upland plains; they are associated with soils from residually weathered shales and slates with thin gravelly colluvial surface layers. These yellow soils are generally less well-drained than the red soils. Due to the relatively high rainfall, the weathering of the underlying rock is moderate to high. On mid- and upper slopes the subsoils are clayey, moderate to strongly structured, with red and yellow geogenic mottling, and with a fairly low pH and base status. On lower concave slopes the subsoil becomes gleyed (wet and hydromorphic). The well-leached Pinedene and Tukulu forms are usually associated with shale fynbos or with renosterveld (on the less leached, residual soils).

Large areas of the western and southern coastal forelands and the inland valleys are underlain by shales and slates of the Malmesbury and Bokkeveld Groups. Depending on rainfall, terrain position and slope gradient, a series of progressively more developed soils occur from crest positions to the valley floor. In drier areas and steeper terrains shallow (lithosolic) soils of Mispah and Glenrosa forms are dominant. As the slope gradient deceases and/or the rainfall increases, clay migration and the formation of clay-enriched subsoils become prominent. On midslopes the dominant soils are of Swartland and Sterkspruit forms. Due to a higher degree of wetness as a result of lateral soil water movement, soils on lower slope positions are characterised by a bleached, pale-coloured E-horizon above a structured cutanic B (Klapmuts and Estcourt forms). In concave or level foothill positions the degree of wetness is such that a gleyed G-horizon (Kroonstad form) replaces the cutanic B-horizon. The soils with cutanic and G-horizons are collectively known as duplex soils because of the significant difference in clay content between the A/E and clay-enriched subsoil horizons. The difference in clay content is partially due to clay migration, but it is significantly enhanced by movement of surface soil material from upslope to lower slope positions through creep and slip and removal of the fine silt and clay from the material that develops into the A- and E-horizon. The lower the clay content of the A/E in a specific climatic zone, the lower the pH and base status. The typical vegetation type associated with these soils is shale renosterveld.

The pH and base of the lithosolic and duplex soils vary greatly as a function of prevailing climate. In warm, dry valleys (e.g. the Little Karoo and eastern Breede River Valley) the soils are normally base-saturated with a slightly acid to neutral pH. Free lime may be present as well. In more humid climate zones these soils are generally acid to very acid throughout the profile. It is the rainfall which largely determines the exchange characteristics of the soils. The very high cation exchange capacity values of the cutanic horizons in Caledon compared to those of Witzenberg, are an indication that the Caledon subsoils contain more 2:1 clay minerals and less kaolinite than those of Witzenberg. This might be an indication of greater shrink-swell and stronger structural development that negatively affects porosity, aeration and wetness. The low-rainfall soils are normally associated with the shale renosterveld and the high-rainfall soils with shale fynbos.

Duplex soils underlain by shales and slates are common in synclinal valleys such as the Langkloof and upper Olifants River Valley. Sandy colluvial material from the surrounding quartzite mountain slopes covers the residually weathered clays. The result is soils with a very sandy, pale-coloured A/E-horizon, periodically saturated with water, on gleyed, prismatic, clayey subsoils. Although the residual clay layers might be base-saturated and even saline, the sandy surface horizons are usually acid and base-unsaturated. These are usually covered with sand or sandstone fynbos.

Although granites are generally more resistant to weathering than shales and slates, granites have undergone deep weathering on old erosional surfaces. The granite hills near Darling (supporting granite renosterveld) and Paarl (supporting both fynbos and renosterveld on the crest and lower slopes, respectively), are some of the well-known plutons of the Cape Granite Suite exposed through erosion of the younger cover rocks. Due to resistance of granite, rock outcrops and very shallow soils of the Mispah and Glenrosa forms are dominant on the crest and upper slope positions on these low granite mountains. Where the slope becomes less steep with a straight slope gradient, soils of the Swartland and Sterkspruit forms, similar to those associated with shales and slates, start to develop. On level and concave slopes, soils of the Klapmuts, Estcourt and Kroonstad forms are found. Because of the coarse sand grade of the quartz particles in the weathering products from granite, sorting and removal of the fine soil fraction through creep and wash usually results in a coarse sandy overburden with low clay content. The coarse sandy overburden is highly permeable and leached, even under fairly low rainfall such as in the Kamiesberg Mountains, to form acid, low base-saturated A- and E-horizons. These support granite fynbos.

Heuweltjies are a major micro-relief feature in some units of both the West Coast, in FRs 8 Breede Shale Renosterveld, and of the South Coast, in FRs 11 Western Rûens Shale Renosterveld. These are generally raised mounds of soil, regularly spaced and up to 10–20 m in diameter and 5 m high. The density varies from almost continuous in the Piketberg area, to sparsely scattered. The name Tygerberg ('Leopard Mountain') is derived from the grass-dominated heuweltjie patches that turn yellow in summer. Heuweltjies are not confined to renosterveld: they are prominent in Succulent Karoo and even in Fynbos, where shale layers are within a few metres of the surface. They are particularly prominent in the winter-rainfall region (Lovegrove & Siegfried 1986, Knight et al. 1989). Heuweltjie soils are generally more base-rich, particularly in calcium, compared to the surrounding soils. In low-rainfall areas the subsoil is calcareous and soft or hardpan carbonate horizons and dorbank are common.

Heuweltjies have been attributed to various causes—geomorphic (heave mounds due to mineral accumulation) and biotic. Among the biotic contenders were mole rats *Cryptomys hottentotus* (differential deposition forming mounds in waterlogged areas) and plants (litter accumulation), but the current consensus is that they are (or were in some areas) the underground mounds of harvester termites (*Microhodotermes viator*; Lovegrove & Siegfried 1989). Floristically they are varied and may differ from surrounding communities by supporting predominantly annuals, grasses or thicket elements. These different communities are probably determined by rainfall and grazing pressure (Knight et al. 1989). In many areas, heuweltjies are preferentially used for burrows by aardvarks (*Orycteropus afer*), porcupines (*Hystrix africaeaustralis*) bat-eared foxes (*Otocyon megalotis*) and historically by many other species, and (in waterlogged seasons or when covered by thicket) as resting areas by herbivores, which may also play a role in their community dynamics. The significance of heuweltjies in renosterveld grazing and animal ecology is not known, but presumably harvester termites were, and continue to be, an important ecological component in renosterveld ecology.

2.3.2 Sandy Soils of Quartzitic Fold Ranges

Mountain Slope Soils

The hard, resistant Peninsula and Nardouw Formations and Witteberg sandstones and quartzites weather slowly and generally give rise to stony, very sandy soils (Figure 4.5) with a clay content of less than 5% and extremely low levels of free iron

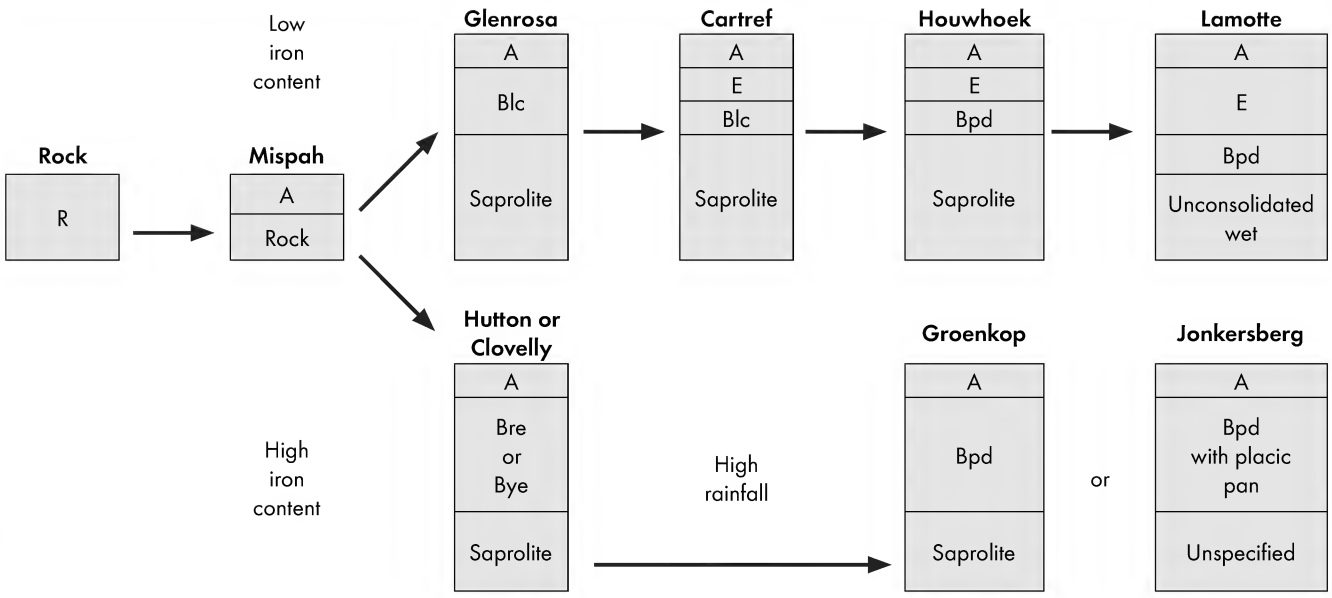

Figure 4.5 Mountain slope soils. Abbreviations: A = orthic A-horizon; E = E-horizon; Blc = lithocutanic B-horizon; Bre = red apedal B-horizon; Bye = yellow-brown apedal B-horizon; Bpd = podzol B-horizon.

oxides. On steeper slopes the weathering products are continuously removed by erosion and accumulate as pediment fan or talus slope materials of varying thickness and extent. On steep sloping mountain ridges, especially the northern slopes in the eastern zone, rock outcrops and very shallow soils predominate. Less steep slopes are generally characterised by pale-coloured, shallow sandy soils of the well-drained Mispah and Glenrosa forms. On more even and concave sites moderate to poorly drained Cartref and Houwhoek forms develop. In lower-lying positions with fairly thick accumulations of weathering products soils of the Lamotte form are found. In areas with a fairly high rainfall (e.g. George and Grabouw) the full range of soil forms from Mispah to Lamotte can occur. As rainfall decreases, soil forms with a podzol B become less prominent and may completely disappear in the relatively dry northern section. Although soils developed from quartzites and sandstones are generally acid, the degree of acidity increases with an increase in rainfall, especially in the podzol B-horizon. All the sandstone and quartzite fynbos vegetation units are associated with these soils.

The less quartzitic layers in the Table Mountain Group with more iron oxides weather faster than the pure quartzite and sandstones and produce a yellowish or reddish material with a higher clay content than the pure quartzites. On upslope positions these materials qualify as Hutton or Clovelly forms. Under high-rainfall conditions, soils with a podzol B without (Groenkop form) or with (Jonkersberg form) a placic pan directly under the orthic A, can develop. The dense and cemented placic pan has a very low permeability and results in localised wet spots in the landscape and restricts root penetration. The absence of an E-horizon is due to the higher clay and iron content that primarily retards the loss of organic carbon required for the soil to become bleached. The soils with a podzol B-horizon are usually extremely acid with pH values as low as 3.5–4.0, while soils of the Hutton and Clovelly forms in the drier regions are only moderately acid with pH values higher than 4.5.

The shale bands associated with the quartzites and sandstones are more weatherable and give rise to deeper, more heavily textured lithosolic soils and even soils of duplex form. Due to the fairly high rainfall in the high-elevation localities where the shale bands occur, these soils are moderately to highly leached with a low base saturation. These soils support shale fynbos, shale renosterveld or karoo vegetation. In many places, however, the weathered shale bands are covered with sandy colluvium from the higher-lying quartzites and sandstones, and carry sandstone fynbos communities.

Pediment and Valley Floor Soil

A great range of sandy soils, usually acid and highly leached, have developed from pedimented colluvial and alluvial accumulation products in intra- and intermountain valleys and on footslopes associated with quartzitic mountain ranges (Figure 4.6). Depending on the source material, the accumulation products vary in free iron oxide content. Sand fynbos is supported by these soils.

On iron-poor parent materials the initial upslope soils usually qualify as Oakleaf or Tukulu forms. With sufficient rain these soils become podzolised. The dominant soil form is Lamotte with a well-developed organic-rich B-horizon and rarely Concordia form with a poorly developed B-horizon. In these soils the E-horizon is usually very thick and the B-horizon might be as deep as 1.5 m. In wetter positions lower down the slopes, the podzol B usually disappears to form Fernwood soils.

In well-drained or drier areas with iron-rich, sandy parent material, yellow (Clovelly form) or red (Hutton form) soils usually develop in upslope positions. With an increase in rainfall or in lower positions, bleached A- and E-horizons develop through removal of iron oxides and, to a lesser extent, clay (Constantia form). In lower positions with a wetter water regime, typical podzolic soils develop with pale-coloured A/E-horizons on a dark reddish brown to yellow, iron- and humus-enriched alluvial B-horizon (Lamotte and Concordia soil forms). The main difference between these soils is that with more leaching in mid- and lower positions, the uniform clay content (5–7%) in the Constantia form differentiates into very sandy A- and E-horizons (<2% clay) and clay increases to up to 10% in the podzol B. The high organic carbon content in the podzol B acts as an absorption reservoir for exchangeable cations as well as

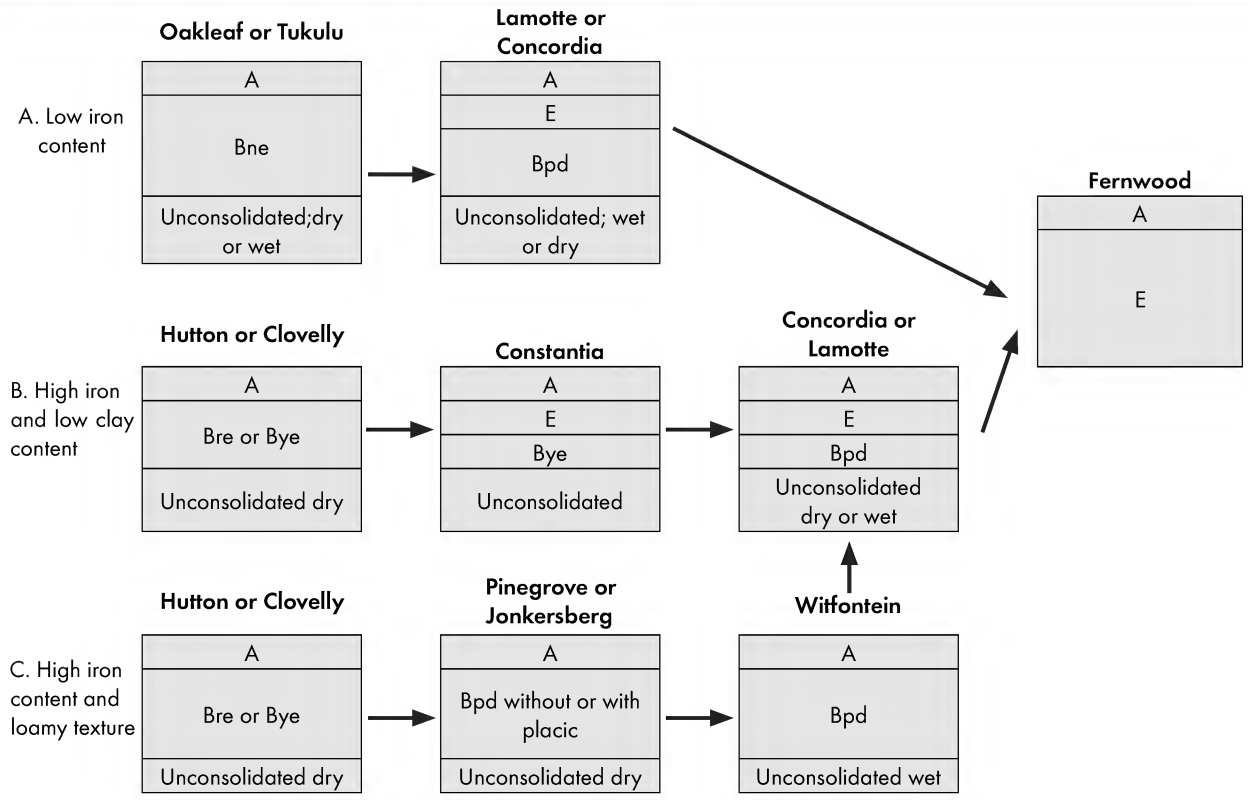

Figure 4.6 Pediment and valley floor soils. Abbreviations: A = orthic A-horizon; E = E-horizon; Bre = red apedal B-horizon; Bye = yellow-brown apedal B-horizon; Bpd = podzol B-horizon; Bnc = neocarbonate B-horizon.

trace elements. There is also a distinct decrease in base saturation at pH 7 from 50–70% in the Clovelly B to lower than 30% in the more leached Lamotte soils.

Although, morphologically, all the soils on the valley slopes appear to be well-drained, the Lamotte and Fernwood in particular may be subject to various degrees of wetness during the rainy season. One of the main causes may be the partially weathered base rock or residual or transported clays below the solum, giving rise to perched water tables. In the Lamotte form, wetness is sometimes manifested in a vesicular hardening (ortstein hardening) of the podzol B-horizon. Along the main drainage channels and depression areas the topsoil of the Lamotte and Fernwood forms is generally dark-coloured and poorly drained, with abnormally high accumulations of slightly decomposed organic material.

The well-drained red and yellow colluvium usually qualifies as soils of the Clovelly and Hutton forms. In midslope positions a podzol B-horizon without (Pinegrove form) or with (Jonkersberg form) a placic pan develops directly below the orthic A-horizon. In lower or concave slope positions that tend to be wet, soils of Witfontein form, similar to Pinegrove, develop on unconsolidated material, with signs of wetness. These soils are extremely acid with pH($CaCl_2$) values usually of < 4.0 and base saturation of ≤ 20% at pH 8. The carbon content in the topsoil ranges from 2.0% to as high as 4.5%.

2.3.3 Coastal Plain Soils

Young Dune Sands

Along the West Coast most of the soils (Figure 4.7) have developed from recent drift sands, locally overlying more clayey fluvial deposits or residually weathered clayey materials. Near the coast the sands are highly calcareous and stratified (Namib form). Inland the lime content gradually decreases through leaching. Depending on rainfall and the initial iron content of the recent sand, different combinations of soils could develop. With a low iron content the Namib form can change with age to Augrabies, Fernwood or Lamotte forms. With higher iron content the Fernwood is replaced by Hutton (drier and warmer areas) or Clovelly (wetter and cooler areas) forms. In the Vredendal area the shallower Hutton variants are classified as soils of the Garies form with relict duripans in the subsoil. With increase in age or rainfall, these soils can further change to Constantia and finally to a Lamotte form. The strandveld vegetation units occur on soils of the Namib and Augrabies forms while the sand fynbos is generally associated with other soil forms.

Scattered along the inland section of the West Coast are fairly large areas of red (Hutton form), yellow (Clovelly form) or grey (Fernwood form) aeolian windblown deposits. These soils are older versions of the younger soils that occur closer to the coast and support sand fynbos.

Especially along the northern section of the West Coast with a fairly low annual rainfall (115 mm) the Hutton, Garies and Clovelly sequence of soils is relatively poorly leached, with neutral to slightly acid pH, base-rich especially in the topsoil, with high concentrations of exchangeable magnesium. Although there is a slight decrease in pH and base status from the Hutton to the Clovelly, soils of the Clovelly form are far less leached than similarly textured Clovelly soils near Knysna. The two main reasons for this difference are the difference in rainfall and the salty sea mist which is common along the West Coast. Soils of the Fernwood and Clovelly forms in the Redelinghuys area with an average annual rainfall of 250 mm are extremely acid (pH of < 4.5) with a low base status.

In localities where the sand cover over the more clayey underlying materials is relatively thin, duplex soils (e.g. Estcourt and Kroonstad forms) support renosterveld.

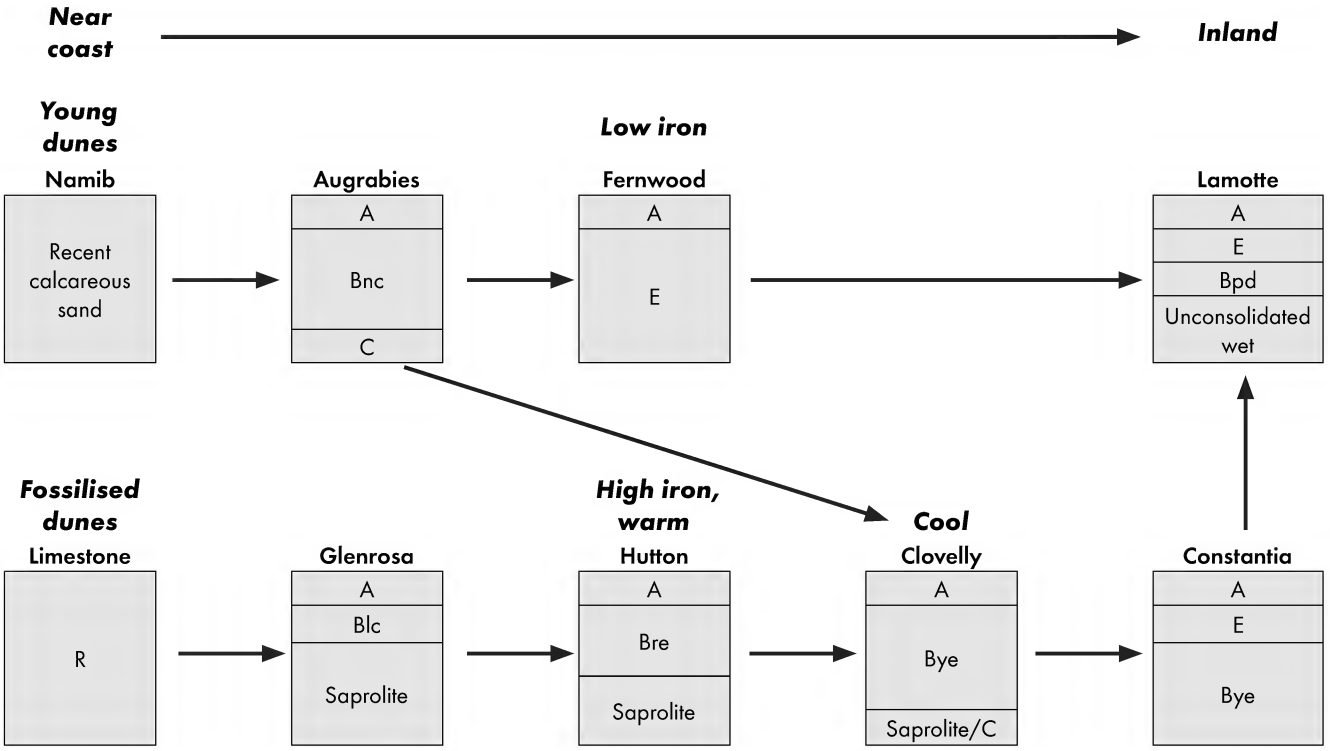

Figure 4.7 Coastal plain soils. Abbreviations: A = orthic A-horizon; E = E-horizon; Blc = lithocutanic B-horizon; Bre = red apedal B-horizon; Bye = yellow-brown apedal B-horizon; Bpd = podzol B-horizon; Bnc = neocarbonate B-horizon.

Fossilised Dunes

In many areas along the West and South Coast old dunes have become fossilised to form lime-rich aeolinites, usually with a thin, hard laminar capping. These aeolinites weather relatively rapidly. Initially shallow soils of the Coega and Glenrosa forms develop from the aeolinites. With age or with increased rainfall, yellow apedal soils (Clovelly form) develop, which with time can develop a bleached E-horizon without (Constantia form) or with (Lamotte form) a podzol B. In warm, dry areas and iron-rich limestone even red apedal soils may develop (Hutton form). The soils of the Coega and Glenrosa forms associated with aeolinites contain free lime and are base-saturated with alkaline pH values. Calcium is the dominant exchangeable cation. Many of these soils contain high levels of extractable phosphorous but it is unavailable to plants due to the formation of water-insoluble calcium phosphates. These soils support strandveld on the West Coast and limestone fynbos on the South Coast.

An interesting weathering feature in the fossilised dune sands and locally in recent dune sands (e.g. Bredasdorp and Knysna) is that the weathering front is not concordant to the soil surface, but has tongue-like extensions resulting in potholes. On the Bredasdorp coastal plain round pockets of moderately to highly leached, usually acid soils of the Clovelly and Constantia forms are found in a predominantly very shallow Coega and Glenrosa soil landscape. This irregular weathering pattern is probably associated with preferential weathering and leaching along roots of deep-rooted perennial shrubs of the local limestone fynbos.

2.3.4 Soils Associated with Silcrete and Ferricrete

Silcrete (supporting silcrete fynbos) and ferricrete (supporting ferricrete fynbos) are respectively silica- and iron-cemented hardpans. Silcrete probably developed during the Miocene and Pliocene in sandy/gravelly quartz-rich, lower-slope surface deposits overlying saline and/or alkaline clays throughout the western and southern forelands. As a result of the high pH in the clays, silica becomes soluble. Through capillary rise the silica-containing groundwater moves up in the profile and silica precipitates and cements on drying (Smale 1973).

Ferricrete develops on old lower slopes with a fluctuating water table. Due to hydromorphic conditions iron is reduced in the permanently saturated zone and moves into the nonreduced overlying zone with a rise of the water table. On drying and lowering of the water table, the reduced iron becomes oxidised and precipitates as iron oxides in the zone of water fluctuation. If this process continues long enough, it forms a continuous, indurate iron pan through the cementation of the individual soil particles (Alexander & Cady 1962). Ferricretisation is ongoing in sandy soils with fluctuating water tables. Ferricretes occur where the sand has been eroded and the iron pan exposed.

Due to a drop in sea level during the Pliocene and later, the coastal foreland was subjected to intense dissection and erosion of the weathered surface material (Hendey 1983a). Today, as a result of their hardness and resistance to weathering, silcrete, in particular, and ferricrete occur as remnants of spatially more extensive hardpans, usually on crests and upper slopes. On exposure, silcrete weathers slowly to produce a quartz-rich, sandy surface layer. Depending on the thickness of the sandy layer and the degree of breakdown of the underlying silcrete, Mispah and Glenrosa soil forms occur. As a result of the sandy and quartzitic nature of the weathering products, these soils are generally acid and base-unsaturated, even under conditions of relatively low rainfall. Ferricrete weathers faster than silcrete. The depth of weathered material can range from less than 40 cm to as deep as 1 m with an increase in rainfall. A variety of soils can develop in the weathered material, including Wasbank, Glencoe and a variety of podzol soils with and without E-horizons. Because these soils have undergone two cycles

of soil formation, the clay content is generally low and the soils are highly leached, with low pH.

2.3.5 Other Soils

Many floodplains of the rivers in the Fynbos Biome with surrounding quartzitic and sandstone mountains are covered with deep sandy alluvium. Soils of the Dundee form are found on the youngest alluvium. Depending on iron content, the older alluvium away from the river may develop into a variety of soil forms that may include sandy, apedal yellow (Clovelly and Pinedene) or grey (Oakleaf and Tukulu) soils. Under conditions of relatively high rainfall pale-coloured soils of the Fernwood form and podzolic soils can also develop. These soils are generally acid with a low base status and are characterised by either alluvial fynbos or alluvial renosterveld.

Near Nieuwoudtville and on the Hantam Plateau basic igneous dolerite rocks occur. Dolerite weathers on relatively level land surfaces to form moderately deep, red, swelling clays (Arcadia form). On sloping, steeper land surfaces the depth of weathering is restricted, and shallow soils of the Glenrosa and Hutton forms develop. Due to the fairly low rainfall in the doleritic areas the soils are base-saturated, with a neutral pH. The heavy clayey dolerite-derived soils typically support dolerite renosterveld.

2.4 Current Climatic Patterns

2.4.1 Megaclimatic Framework

The macroclimates of the two African mediterranean-type ecosystems (the North African portion of the Mediterranean and the Fynbos Biome), show symmetric features (Goudie 1996). The summers in both regions are hot and dry, a result of the poleward migration of high-pressure (anticyclonic) Hadley Cells. In the Cape region the Hadley Cell offshore of southern Africa is located near 32° S in winter, while in summer it is centred near 37° S. The hot summers are associated with a high frequency of trade-winds (the Southeaster). In winter the region is under the influence of the westerlies and their associated disturbances (see Tyson 1986 for a detailed account). In the Cape region the major climatic feature in winter is the occurrence of cyclonic fronts and their associated northwesterly winds, bringing abundant rain. The influence of the winter rainfall, diminishes to the east, where the relative contribution of equatorial air is associated with summer rainfall (see Section 2.1 in Chapter 9 on Savanna on the origins and dynamics of the summer-rainfall regime in the eastern part of southern Africa). Especially in spring and autumn southerly winds bring orographic rain to the south-facing coastal mountains lying south of 33° S and east of 20° E—this is associated with frontal systems that pass south of the continent. As a result, the climatic stations to the east of this show a bimodal rainfall pattern (Allen 1996).

It is presumed that the mediterranean-type climate became established in the Cape at the end of the Pliocene, about 3 mya when the Hadley Cell was located above the South Atlantic Ocean and assumed a relatively fixed position relative to southern Africa (Hendey 1983b, Deacon et al. 1992, Allen 1996). However, there is evidence that the Antarctic circumpolar current and the onset of mediterranean-type climates may have been initiated as early as 33 mya (Scher & Martin 2006).

2.4.2 Regional and Local Climate

Mean annual precipitation (MAP) averaged over the total area of the Fynbos Biome is about 480 mm. This is highest for the fynbos (FF units) at about 540 mm, followed by 370 mm for renosterveld (FR units), and 350 mm for strandveld (FS units). These and some other modelled (nonstation) data below (Schulze 1997a) can be regarded only as approximate, especially with the great topographical diversity in the fynbos region and few confirmatory weather stations on the mountains. MAP is lower on the lowlands of the coastal belt (especially west of Mossel Bay), increasing to much higher values on the mountains nearer the coast, but lower on isolated fynbos island mountains in the Karoo of the interior. Thus, for example, the rainfall on the coastal belt in the vicinity of Herold's Bay increases greatly on the first mountain range of the Outeniqua and remains greater than the rainfall on the inland Groot Swartberg range despite the higher altitude of the latter (Figure 4.8). The lowest MAP is found along the northern parts of the western coastal plain, with a minimum of roughly 100 mm for the FFd 1 Namaqualand Sand Fynbos. The highest MAP averaged over the vegetation unit is found in FFs 30 Western Altimontane Sandstone Fynbos and FFs 11 Kogelberg Sandstone Fynbos (both with MAP over 1 300 mm). The station with the highest measured MAP (3 190 mm at an altitude of 1 219 m at Jonkersnek, Jonkershoek) in South Africa is in Kogelberg Sandstone Fynbos. Of all the vegetation types in the whole mapping area (South Africa, Lesotho and Swaziland), MAP most closely approaches equality with mean annual potential evaporation (MAPE) in Kogelberg Sandstone Fynbos (91% of MAPE) and Western Altimontane Sandstone Fynbos (87% of MAPE).

In all the seven north-south pairs of vegetation units on the generally east-west-trending mountain ranges from the Klein Swartberg, Kammanassie and Outeniqua Mountains in the east to the Hex River and Riviersonderend Mountains in the west, MAP is consistently higher in the respective southern unit when compared to that of its northern counterpart. For example, MAP in the FFs 19 South Outeniqua Sandstone Fynbos is more than 50% greater than that in the FFs 18 North Outeniqua Sandstone Fynbos (see also Figure 4.8). There are also large differences in solar radiation between southern and northern slopes in winter. In this season, north-facing slopes of 20° receive three to five times as much energy than equivalent slopes facing south (Fuggle & Ashton 1979). In summer, the solar energy received daily differs little between north- and south-facing slopes of less than 30°.

Coefficient of variation of annual precipitation varies from < 20% on many of the main mountains in the southwest and south of the biome to > 35% in the northern parts of the western coastal belt.

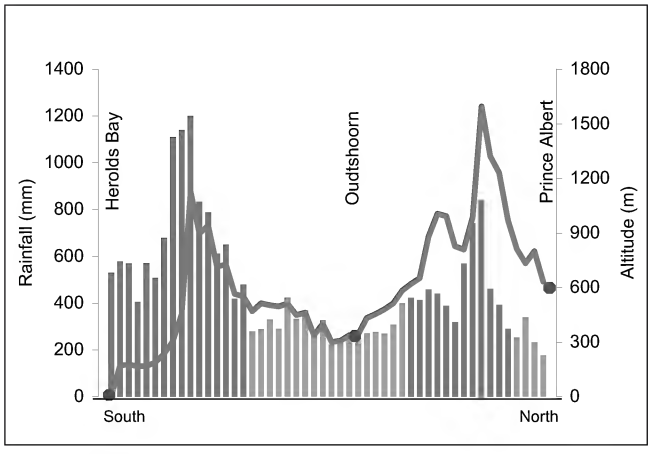

Figure 4.8 Mean annual rainfall along a south–north altitudinal gradient from Herold's Bay on the coast, across the Outeniqua and Swartberg Mountains to Prince Albert, via the Oudtshoorn basin. Dark blue bars represent rainfall in areas in the Fynbos Biome and light blue bars rainfall in karroid and thicket areas. The red line represents altitude above sea level. Green dots represent towns.

The Fynbos Biome has a wide variation in seasonality of precipitation (Figure 4.9). Most of the biome receives either winter or even rainfall (according to definition of Bailey 1979). The area of 'strong winter rainfall' is limited to a section of the West Coast centred on Saldanha and St Helena Bays. However, some of the western parts of the 'winter rainfall' zone are marginal to 'strong winter'. The eastern boundary of the 'winter rainfall' zone extends roughly to the lower Breede River Valley and to the north includes the Roggeveld Escarpment and the Hantam Plateau area north of Calvinia. The 'even rainfall' zone includes much of the southern Cape as well as the renosterveld areas along the Nuweveld Escarpment. Some of the easternmost islands of fynbos, including several vegetation types of the biome (e.g. on the Grootrivierberge and Klein-Winterhoekberge) in the Eastern Cape, lie marginally in the 'summer rainfall' zone.

As a consequence of the winter concentration of rainfall in the west, the solar radiation for winter in the southwestern part of the biome is lower than elsewhere and at any other time of year in South Africa (< 12 $MJ.m^2.day^{-1}$ in July from Saldanha Bay to Cape Agulhas).

Cloud cover on the higher mountains is frequent in the west in the dry summer and driven by strong winds, and occurs predominantly on the summits and southern and southeastern slopes. Over 500 mm of water may be precipitated per year from wet stratus cloud without being recorded in standard rain gauges (Fuggle & Ashton 1979). Schulze (1997b) reports more than 600 mm per annum of orographically induced moisture from fog (not recorded by standard gauges) in the Jonkershoek Mountains near Stellenbosch.

Snowfalls occur on the higher mountains of the southwestern parts of the Western Cape, with a frequency estimated at 5.4 falls per year and peaking in late July (Schulze 1965). The snowline is very seldom seen below an altitude of 1 000 m. Snowdrifts of more than one metre deep can occur on high plateaus such as Fonteintjiesberg (1 989 m) in the Hex River Mountains, with snow cover sometimes persisting for two weeks or more. Snowfalls can occur here into early summer (December). There is anecdotal evidence that the duration of persisting snow has declined over the entire region over the past few decades.

Relative humidity is highest (> 70%) along the coast in summer but with high values also extending inland in winter, especially on the mountains.

Temperatures are generally the lowest on the high mountains (mean annual temperatures of less than 12°C) and higher in the lowlands and tend to be the highest near low-lying parts of the Karoo (mean annual temperatures greater than 19°C), but more ameliorated near the coast with mean annual temperatures closer to 16°C.

The lowlands near the coast are generally frost-free. However, frost does occur on higher-lying regions and towards the interior. Thus, for example, the average number of days with heavy frost (screen minimum temperature < 0°C) is 0.3 for Paarl, 3 for Riversdale, 12 for Grabouw, 14 for Ceres and 93 for Sutherland.

Temperature data for the mountains are limited. On the summit of Table Mountain (Cableway) at an altitude of 1 067 m, mean monthly maximum and minimum temperatures are 30.3°C and –0.2°C for January and July, respectively. To estimate the likely temperatures on two of the highest peaks in the Fynbos Biome, namely Matroosberg, Hex River Mountains (altitude of 2 249 m), and Seweweekspoort Peak, Klein Swartberg range (altitude of 2 325 m), we applied seasonal temperature lapse rates calculated for mountains of the southwestern Cape and separately for the southern Cape (Schulze 1965) to nearby weather stations (Matroosberg–Helpmekaar and Amalienstein, respectively). Mean monthly maximum and minimum temperatures approximate 28.7°C and –8.9°C for the summit of Matroosberg and 30.1°C and –12.2°C for the summit of Seweweekspoort Peak for January and July, respectively.

One of the highest temperatures ever measured (46.1°C) in the biome was in January at a low altitude near the karroid edge of the biome at Clanwilliam. This absolute figure compares with a mean monthly maximum temperature of 44.1°C and a mean daily maximum temperature of 35.4°C for the same station and

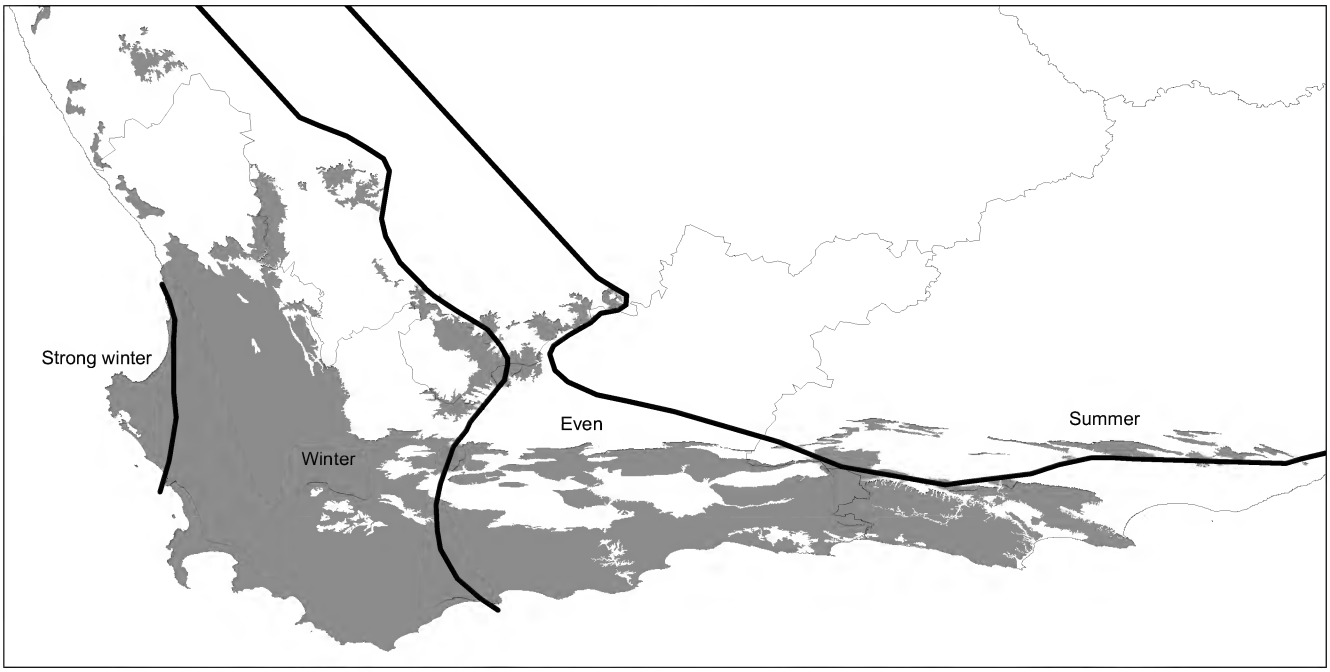

Figure 4.9 Classes of rainfall seasonality for the Fynbos Biome (shown in red) using mean winter rainfall (April to September) as a percentage of mean annual rainfall (after Bailey 1979). Rainfall data were interpolated from rainfall station data. Strong winter (80% and over), winter (60–79%), even (40–59%), summer (20–39%); strong summer (0–19%) is not encountered in the Fynbos Biome.

L. Mucina

Figure 4.10 Blanket of fog created by the ascending moisture-laden 'Southeaster' (trade winds) blowing over the Kogelberg (Western Cape).

month. Even well within the biome there are also some areas of high summer temperature. Wellington–MUN recorded an absolute temperature of 45.6°C in January. This figure compares with a mean monthly maximum temperature of 38.5°C and a mean daily maximum temperature of 31.2°C for the same station and month.

Mean annual potential evaporation on the lowlands of the coastal belt south of the Riviersonderend–Langeberg Mountains is < 2 000 mm, dropping to < 1 800 mm and in parts even < 1 600 mm south of the Outeniqua and Tsitsikamma Mountains. By contrast, the lowlands north of False Bay have a higher mean annual potential evaporation, i.e. greater than 2 000 mm, increasing to more than 2 200 mm north of Malmesbury and to greater than 2 400 mm in the Olifants River Valley, the coastal belt of Namaqualand and the Roggeveld Escarpment. Values on the higher mountains close to the coast are below 1 400 mm.

Fuggle & Ashton (1979) provide a useful summary of the occurrence of wind in the Fynbos Biome. The region's entire coastal belt is characterised by strong winds. Summer winds are dominantly southeasterly to southerly, usually picking up in midmorning and reaching greatest strength in the evening, although often persisting at gale force for days. They are responsible for the orographic summer mist precipitation and the associated 'Table Cloth' and 'Hottentot's Blanket' on the mountains (Figure 4.10). Winter winds dominate from the northwest (prefrontal) and southwest (postfrontal). Sea breezes exert an influence when gradient winds are light, appearing as shallow northwesterly to westerly air drifts along the Atlantic coast but as shallow southeasterly flows on the South Coast. In summer the sea breeze over False Bay reinforces the southerly gradient winds, giving rise to maximum wind velocities in the early afternoon. Land breezes do not occur in the southwestern part of the Western Cape due to the very low sea temperatures.

From Cape Hangklip eastwards a slight sea breeze influence is evident throughout the year, but prevailing winds are roughly easterly and westerly. The main difference between winter and summer winds east of Mossel Bay is the high frequency of easterly winds in summer (greater than 25%). The warm Agulhas Current off the coast provides a land-sea temperature gradient sufficient for land breezes to develop on calm, clear nights. Katabatic drainage down the major valleys cutting through the mountain ranges reinforces the land breeze, giving moderately strong offshore winds seaward of major valleys. In the interior there is much less wind than on the coast, the percentage of calms is higher and in the west a greater westerly component is evident in both summer and winter. In the eastern interior the prevailing winds are easterly to southeasterly in summer and northwesterly in winter.

The entire coastal belt is subject to occasional hot desiccating gusty winds (berg winds), especially in winter. These outbreaks of subsiding air heated by compression become more marked eastward along the coast. The wind blows at right angles to the coast and is responsible for temperature rises of over 10°C in just a few hours. They are associated with approaching low pressure systems and often precede frontal systems.

Wind speed can be high, especially in the west. In Cape Town (Wingfield), the wind speed exceeds 26 km per hour, almost half of the time in January (Schulze 1965). For around 20 hours of this month, wind speed exceeds 42 km per hour. Wind speed and frequency can be expected to be considerably higher on mountain tops.

Lightning frequency and hail are rare in the extreme western parts of the biome but increase eastwards. Yet even in the extreme eastern parts, lightning ground-flash densities remain below 2 flashes per km^2 per year (Schulze 1997a).

3. Vegetation Types of the Fynbos Biome

There are three major vegetation complexes within the Fynbos Biome—fynbos, renosterveld and strandveld—described below.

Embedded within the Fynbos Biome are edaphically specialised vegetation units of azonal nature (Table 4.1), such as those of coastal vegetation (see Chapter 14) or inland azonal vegetation, including freshwater wetlands and salt pans and alluvia (see Chapter 13). The remnants of the afrotemperate and coastal subtropical milkwood forests are of intrazonal nature and are described in Chapter 12.

3.1 Fynbos

Fynbos (derived from the Dutch 'fijn-bosch' and pronounced 'feinbos') means 'fine bush', with a Dutch connotation for 'kindling'—as opposed to fire-wood. It is an evergreen, fire-prone shrubland characterised by the presence of restios (wiry, evergreen graminoids of the Restionaceae), a high cover of ericoid shrubs (fine-leaved, principally in the families Ericaceae, Asteraceae, Rhamnaceae, Thymelaeaceae and Rutaceae), and the common occurrence of proteoid shrubs (exclusively Proteaceae). It is thus often considered a 'heathland', which it resembles in structure and function, but strictly only ericaceous fynbos is truly a heathland (Cowling et al. 1997). Other important features of fynbos are the presence of leaf spinescence, high sedge (Cyperaceae) cover and low grass cover in mature phases of some facies (Campbell 1985). Campbell (1985) ascribed the origin of the botanical use of the term 'fynbos' to

Table 4.1 Zonal, intrazonal and azonal vegetation units (or groups of units) within the Fynbos Biome. For the discussion on the concepts related to zonality see Chapter 13 on Inland Azonal Vegetation.

Vegetation unit	Extent (km²)	Zonality status
FF Fynbos	59281	zonal
FFq 1 Stinkfonteinberge Quartzite Fynbos	49	extrazonal [A]
FFd 1 Namaqualand Sand Fynbos	939	extrazonal [A]
FFg 1 Kamiesberg Granite Fynbos	36	extrazonal [A]
FR Renosterveld	27962	zonal
FRg 1 Namaqualand Granite Renosterveld	706	extrazonal [A]
FS Western Strandveld	3001	intrazonal
Cape Thicket[B]	unknown	intrazonal
F I1 Western Case Talus Forest[C] (part of FOz 1)[D]	unknown	intrazonal
F I2 Western Cape Afrotemperate Forest[C] (part of FOz 1) [D]	unknown	intrazonal
F I3 Southern Cape Afrotemperate Forest[C] (part of FOz 1) [D]	unknown	intrazonal [E]
F VII3 Western Cape Milkwood Forest[C] (part of FOz 7) [D]	unknown	intrazonal
AZf 1 Cape Lowland Freshwater Wetlands [G]	72	intrazonal/azonal [F]
AZa 1 Fynbos Riparian Vegetation [G]	17	intrazonal/azonal [F]
AZa 2 Cape Lowland Alluvial Vegetation [G]	358	intrazonal/azonal [F]
AZd 3 Cape Seashore Vegetation [H]	227	intrazonal/azonal [F]

A isolated patches outside the main Biome extent, embedded within other biome (Succulent Karoo)
B not mapped or classified due to very small extent and lack of data
C nomenclature and code as in Von Maltitz et al. (2003); see also Table 12.1 in this book
D codes FOz 1 and FOz 7 refer to the Forest zonal vegetation units (see Chapter 12 in this book)
E the isolated patches embedded within Fynbos Biome are intrazonal; the Knysna-Tsitsikamma forest region is the largest zonal remnant of the Afrotemperate Forest Biome in Southern Africa
F intrazonal on regional scale; azonal on continental scale
G featured in Chapter 13: Inland Azonal Vegetation
H featured in Chapter 14: Coastal Vegetation

Bews (1925), who applied it to fine-leaved shrublands of both the Cape and the Drakensberg.

We define 'fynbos' in structural terms pragmatically as a shrubland or restioland with a cover of more than 5% Restionaceae, usually containing elements of Ericaceae or other ericoid shrubs and Proteaceae. Ecologically it is naturally dominated by the effect of hot summer fires at intervals of 10–30 (or more extremely 5–50) years, which are fuelled by the fine-leaved shrubs and especially by the Restionaceae. Fynbos occurs mainly on nutrient-poor sandy soils, and less frequently on limestone, leached clay soils derived from shale and granite, and gravelly soils derived from duricrust outcrops and alluvial sediments.

3.1.1 Approaches to Typology of Fynbos

Classification of vegetation of the Cape Floristic Region has been, for descriptive vegetation scientists at least, a challenging and daunting task.

To date there have been six major classification attempts for vegetation in the Cape Floristic Region:

(1) Acocks's (1953, 1975, 1988) veld type scheme.

(2) Braun-Blanquet (floristic-sociological) approach, represented by Taylor, Boucher and their students.

(3) Moll and Bossi's large-scale units based on remote-sensing (Moll & Bossi 1983) and used by Low & Rebelo (1996).

(4) Campbell's (1985) structural classification.

(5) Cowling's Broad Habitat Unit classification (Cowling et al. 1999b, Cowling & Heijnis 2001).

(6) Our classification presented here.

The vegetation classifications of Acocks, Moll, Cowling and this chapter address biome-scale patterns, and are therefore well suited to national management and planning of natural resources. Acocks and Moll's schemes contain a small number of broad units and are thus less successful in summarising the diversity of vegetation in the Cape Floristic Region. The Broad Habitat Units (BHUs) and our vegetation types are far more detailed, and also mapped at a far finer scale. The BHUs are based on three basic sources: geology, climate and centres of endemism. Our approach uses the BHUs, but also includes important characters such as: (1) extensive use of floristic data in delimitation and calibration of the units, (2) differentiated weighting of the importance of geology and climate depending on the broad subcategory of the classified object, (3) application (albeit only to a limited extent) of the concepts of zonality in the unit delimitation, and (4) high-level of GIS precision of definition of boundaries by using more detailed (and precise) GIS sources—leading to a high level of detail recognisable down to 1:250 000 and in places even 1:50 000 scales.

Only the floristic-sociological and structural classifications did not produce a biome-wide map of the region, arguably as they focus at much smaller scales.

The Braun-Blanquet (or 'BB') approach, known as 'phytosociology' or 'phytocoenology' (Braun-Blanquet 1964, Westhoff & Van der Maarel 1978), became the most used method in Europe and was exported worldwide (Van der Maarel 1975). In South Africa this approach has been used in the Savanna and Grassland Biomes, but achieved less success in the Fynbos Biome, where it has been used locally in management plans of some conservation areas.

By addressing the vegetation complexity on habitat (or habitat complex) level, the floristic and structural approaches became a

focus of controversy, which continues today (Linder & Campbell 1979, Campbell 1986c, Cowling & Holmes 1992b). The use of the BB approach was criticised (if not dismissed) in the Fynbos Biome because of the following flaws and difficulties:

(1) Floristic composition requires cover classes but fynbos takes 8–15 years to mature, during which the species canopy cover changes dramatically. In fact, seral stages recapitulate the fynbos series (see below). Thus, at any one time, a large proportion of fynbos vegetation may be too young for sampling.

(2) The composition of many communities is determined by fire (intensity, season, frequency, veld age, past fire history, lottery recruitment from seed banks following fire), and thus the same community may vary in species composition and abundance between fires. This results in different community classifications for the same site.

(3) As a consequence of focusing on mature communities, fire ephemerals and geophytes are not routinely recorded or included into community descriptions. Phytosociological data do not exist for young fynbos, and it is not known whether the community patterns for young communities reflect or are independent of mature fynbos. Data do not even exist as to which communities have markedly distinctive post-fire communities. Some communities have a dominant and high-cover early seral community (usually Asteraceae or Fabaceae), which is completely absent in mature veld, whereas other communities merely change by overtopping of later seral species without much loss of early seral cover. The dynamics of these community changes are unexplored.

(4) We do not understand the geophytic and spring annual communities. These are routinely excluded from phytosociological surveys as they effectively restrict sampling to two or three months of the year. There is some evidence that geophytes are not as geologically restricted in their distributions as many shrubs (phanerophytes). This affects patterns of endemism, with surprisingly many renosterveld geophytes also present in fynbos on sandstone substrates and thus crossing many shrub-based community boundaries, a rare occurrence in shrubs.

(5) The high gamma diversity results in ecologically analogous communities in different areas having different replacement species, not necessarily in the same genus. Consequently, the proportions of replacements between analogous communities will vary between regions and communities to the extent that analogous communities may not be easily detectable.

(6) There are too many species (many of which are identifiable only for short flowering or seeding periods) for the practical identification of species, so that omitted, indeterminate and incorrectly identified taxa will confound floristic analysis. Adequate sampling to resolve these problems will make sampling too expensive.

(7) There are too many species and too many communities, so that a formal (syn)taxonomic synthesis of communities becomes unlikely even given sufficient resources.

(8) Because of the high species numbers it takes a long time to collect field data and also for herbarium identification, making data collection a slow and tedious process. This is not helped by frequent taxonomic name changes, or, less frequently, changes in species and generic delimitation—a constant problem in a rich and diverse flora.

(9) Because of species turnover, floristics will yield biogeographical rather than ecological insights into fynbos.

(10) Time, budgetary and legal constraints require that many studies—especially for Environmental Impact Assessments, Integrated Environmental Management and development applications—have to be completed within a matter of months. It is simply impossible to undertake community-type analyses under these scenarios, and communities are usually merely 'eye-balled', with a brief summary of dominant and Red Data taxa (De Villiers et al. 2005).

The first four issues question the theoretical soundness of procedures used in floristic classification of vegetation, based on a misunderstanding of the floristic-sociological approach. Exclusive study of 'mature' communities or the deliberate exclusion of a floristic segment is not preached: the floristic approach is suited for communities at any stage of development. The lack of understanding of the short-lived synusia (such as those of geophytes and annuals) within the Fynbos and Succulent Karoo Biomes is not a theoretical drawback of the approach, but is due to the wrong application of its sampling procedures. The issues (5) to (8) lament the high diversity and the concomitant high time and identification investment needed, and taxonomic deficiencies. All of these issues are logistical and certainly valid. However, these are surmountable provided there is change in political will that would result in more support for vegetation surveys (including better funding) and steady and genuine progress in plant systematics.

The success of the floristic-sociological approach lies especially in the researcher's or user's ability to read the ecological message in particular species groups. This implies being able to identify all the species and understand their ecology—admittedly a tall order in a region containing over 9 000 taxa. Consequently only a few areas of the Cape Floristic Region have been studied using the floristic approach—far too few to be of use in the compilation of a detailed vegetation map of the entire Fynbos Biome. The floristic classification of the vegetation of the Cape Floristic Region is possible and necessary, but is still a very distant target. It took European phytosociology more than 100 years to develop a unified vegetation system acceptable to the European Union (EU) legislature (Devilliers et al. 1991, Devilliers & Devilliers-Terschuren 1996, European Commission 1995, Rodwell et al. 2002) and applied on a continent-wide scale (NATURA 2000 network of nature reserves, biotope mapping in the EU, etc.). Despite the lack of manpower and current politically motivated lack of acceptance, South African descriptive vegetation scientists should continue building the floristics-based classification system and ensure that it is used at the proper scale in nature management of the Cape.

Many of these arguments also apply to the alternative structural approach proposed by Campbell (1983, 1985, 1986a, b) for fynbos of the mountainous regions. This system was later tested and extended to the South Coast lowlands by Cowling et al. (1988) and Rebelo et al. (1991). Campbell's scheme has the advantage in that it is relatively quick to sample and does not require many years of taxonomic experience to execute. However, its reliance on certain easily identified taxonomic groups, and their cover/abundance, renders it equally problematic to floristic studies in terms of requiring mature veld for sampling (Cowling & Holmes 1992b). It is also problematic in that a comprehensive map of structural types across the biome has never been attempted, although it was shown to be amenable to fine-scale mapping on the South Coast.

The structural classification approach fails in several important theoretical and practical aspects. The most serious theoreti-

cal drawback is the fact that the vegetation structure is of a convergent nature—the same structural phenomena can be encountered under very different habitat conditions. However, this has not proved a drawback in the Fynbos Biome, with the exception of restioid fynbos, where the arid facies and mesotrophic restioid fynbos were easy to separate at the next hierarchical level (Rebelo et al. 1991). Another serious weakness of the approach lies in the link between the vegetation structure and function, assuming that the ecological message can be detected in growth forms. Admittedly, we know even less about it than about the ecological requirements of particular species. Structural classifications are currently the method of choice for rapid, quick appraisals required for conservation monitoring and Environmental Impact Assessments, where floristics are restricted to the documentation of the dominant 10–20 species and the listing of Red Data taxa. Whatever its deficiencies, fine-scale mapping of core areas of the Cape Floristic Region is currently under way based on Campbell's methodology as modified by Cowling et al. (1988) and Rebelo et al. (1991).

There is a clear need for a theoretical integration and development of both floristic and structural approaches as well as for a classification of habitats at a scale finer than vegetation types (Linder 2005a).

3.1.2 Structural Communities in Fynbos

Campbell's (1985) structural approach is based on the cover-abundance in height classes of life or growth forms (e.g. annual grasses, ericoid leaves), single-structural characters (e.g. spinescence, leaf hairiness), higher taxa (e.g. Ericaceae) and dominant species (especially Proteaceae). The interplay between the different structural communities is complex, but clear patterns have been determined.

Within fynbos availability of water appears to be a key element in determining the distribution of structural components across the landscape. Overall, asteraceous fynbos occurs at the most arid extreme, followed by restioid, graminoid, proteoid fynbos and waboomveld, with ericoid and wet restioid fynbos on the moistest extreme. In deep soils with widely fluctuating water tables, shrubs appear to be excluded and restioid and occasionally ericoid fynbos are dominant. This composition appears to be determined by success of post-fire establishment, with shrub seedlings failing to keep in root contact with the dropping water table. In rocky areas, the amount of soil and depth of cracks seem to be important variables for vegetation structure.

Proteoid fynbos (Figure 4.11) is characterised by a high cover of dominant, reseeding overstorey proteoids. These plants are usually tall or emergent, but in ferricrete and silcrete fynbos they may be lower than 1 m. Ferns and evergreen geophytes are prominent, and leafy and wide-leaved sedges are also characteristic. Proteoid fynbos is widespread on the deep and relatively fertile colluvial soils at the foot of mountains. It is often prominent on the Cedarberg shale bands, and more prominent below it than above it. With their deep roots, proteoids exploit deep water unavailable to other fynbos plants, and consequently grow when most other fynbos plants are dormant—the wet season is the major flowering time.

Ericaceous fynbos (Figure 4.11) is dominated by ericoids and a high cover of restioids. Endemic and near-endemic families (Bruniaceae, Penaeaceae and Grubbiaceae) are also characteristic, as is a high cover of sedges. Ericaceous fynbos occurs at higher altitudes than proteoid fynbos, on permanently wet, cool, relatively fine-grained soils with a high organic carbon content. Mists are prominent in summer, especially under southeasterly wind conditions when the orographic cloud known on some local mountains as the 'Table Cloth' or 'Hottentot's Blanket' occurs.

Restioid fynbos (Figure 4.11) is dominated by restioids, with a low cover of shrubs. Because restioid fynbos is dominated by shallow-rooted plants, it occurs on warmer, north-facing slopes that are on shallow or deep soils prone to drought in summer, including dunes and perched sandy plateaus. Restioid fynbos also occurs on waterlogged soils on cooler, south-facing slopes, where root growth is inhibited for much of the year.

Asteraceous fynbos (Figure 4.11) has a relatively low total cover, and often a high grass and elytropappoid cover, and a prominent deep-rooted nonericaceous ericoid shrub component (Asteraceae, Rhamnaceae and Thymelaeaceae). We exclude talus asteraceous fynbos, which does not fit comfortably within this group, as 'waboomveld' (see below). Asteraceous fynbos occurs on the hot, lower, north-facing slopes, on the deeper colluvial soils.

Waboomveld or 'talus asteraceous fynbos' (Figure 4.11) has been long recognised as a fynbos community (Taylor 1963). It is characterised by the presence of *Protea nitida* (waboom), the only stem-resprouting plant in fynbos, a habit which allows it to form a very unusual 2–5 m tall tree overstorey. It is largely confined to the lowest slopes and talus slopes, often on more fertile, deeper soils. The understorey is very varied, but often contains significant nonericaceous ericoids.

Grassy fynbos (Figure 4.11) is characterised by a high grass cover, with an associated high cover of nonproteoid nanophylls and forbs. It is quite distinct from the other fynbos types and has been regarded as a separate grouping, known as 'Eastern Fynbos' (Cowling 1984, Campbell 1985). Grassy fynbos occurs on soils of finer texture and higher nutrient levels, and under conditions of less summer drought than the other fynbos types.

It is apparent that ericaceous and proteoid fynbos are more common on the coastal ranges, whereas restioid and asteraceous fynbos prevail on inland ranges. In addition, higher (wetter) mountains have more ericaceous and proteoid fynbos. Flats and lower ranges are dominated by restioid and asteraceous

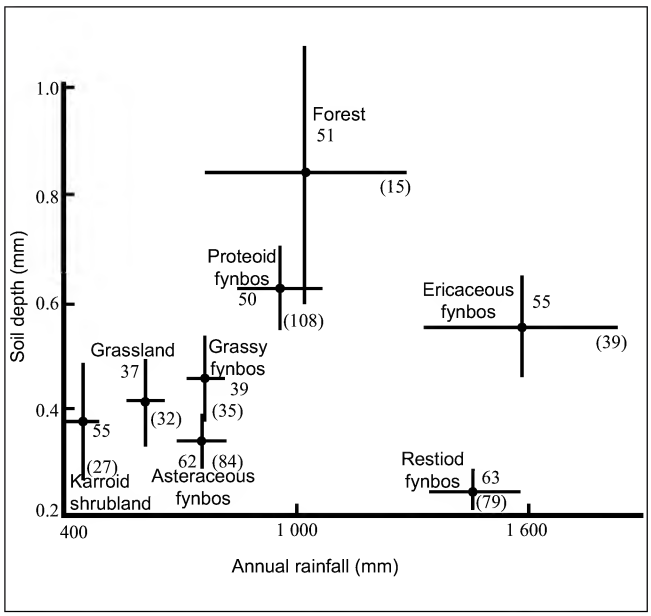

Figure 4.11 Direct ordination of various fynbos shrublands and related vegetation of the southwestern Cape (including forests, karroid shrublands etc.) in relation to annual rainfall and soil depth (courtesy of Oxford University Press, Cape Town).

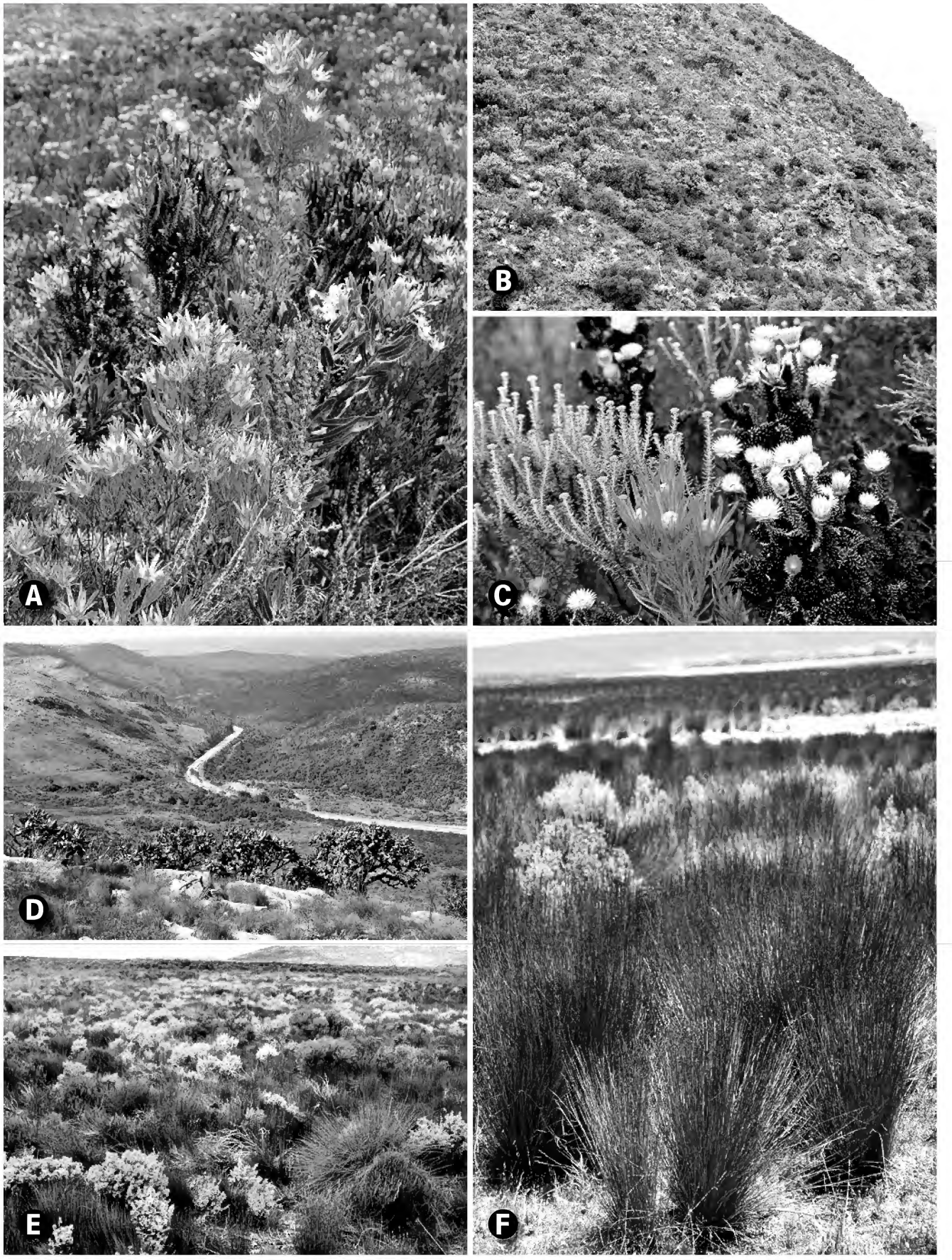

Figure 4.12 Faces of fynbos shrublands: A: proteoid fynbos dominated by *Leucadendron xanthoconus* and prominent *Phaenocoma prolifera* (Potberg); B: waboomveld with tall scattered *Protea nitida* (Du Toitskloof, Limietberg); C: coastal asteraceous shrubland with *Phaenocoma prolifera* and *Metalasia densa* (Betty's Bay); D: grassy fynbos with low tree of *Oldenburgia grandis* (Asteraceae) in the foreground (Howison's Poort near Grahamstown); E: typical ericoid fynbos with *Erica laeta* dominant in temporary wetlands of the Smitswinkelvlakte (Cape of Good Hope); F: restioid fynbos with *Thamnochortus spicigerus* on the Agulhas Plain. Photographs by L. Mucina.

fynbos. In the east, where summer drought is less pronounced and soils are more fertile, grassy types dominate. Thus, in the east, proteoid fynbos is replaced by graminoid fynbos, restioid fynbos is replaced by grassland, and asteraceous fynbos is replaced by grassy shrubland. Richer soils (granites, shales, silcrete and ferricretes), if leached by high rainfall (more than 600 mm per year), contain mainly asteraceous and proteoid fynbos (Figure 4.12). Restioid fynbos also occurs in seasonally waterlogged dune environments.

Although complex, structural types occur predictably across landscapes in fynbos vegetation types. Analogues between units are relatively straightforward and allow easy comparison of ecological gradients between units. Generally there is also an altitudinal zonation in the mountains, with waboomveld, proteoid, ericaceous and restioid fynbos on southern slopes, and asteraceous, proteoid, ericaceous and restioid fynbos on the northern slopes. However, these patterns are modified by soil depth and drainage (Cowling & Holmes 1992b).

3.2 Renosterveld

Renosterveld, or renosterbosveld, literally translates as 'rhinoceros vegetation'. There is confusion as to whether this refers to the historical presence of the hook-lipped or black rhinoceros (*Diceros bicornis*) in this veld type or, more likely, whether it is derived from 'renosterbos-veld' (Boucher 1980). Renosterbos refers to *Elytropappus rhinocerotis*, the dominant plant in this vegetation thought to be so named because reputedly only the black rhinoceros ate it (it is filled with phenolics and eschewed by livestock). A third explanation is the dull, grey appearance of the veld (hence 'Swartveld' and 'Swartland', meaning 'black field' or 'black land'), which is similar in hue to rhino hide (Boucher 1980).

Renosterveld is an evergreen, fire-prone shrubland or grassland dominated by small, cupressoid-leaved, evergreen asteraceous shrubs (principally renosterbos) with an understorey of grasses (Poaceae) and a high biomass and diversity of geophytes (Boucher 1980, Moll et al. 1984, McDowell & Moll 1992). Here we define renosterveld narrowly as excluding (fynbos) types dominated by Proteaceae, Ericaceae or having more than 5–10% cover of Restionaceae. Thus we approximate Campbell (1985) in our approach, in that *Elytropappus*-dominated communities with *Passerina, Phylica* and restioid components considered asteraceous or restioid fynbos types. Our definition is much narrower than that of Moll (Boucher & Moll 1981), but approaches Acocks (1953) for the West Coast. We reject Acocks's 'false' veld types, as a derived type and consider them typical types in their area. However, we include thicket bush-clumps such as those occurring on heuweltjies as a typical renosterveld element. Renosterveld occurs predominantly on clay-rich soils derived from shale and granite and, to a lesser extent, silcrete.

Apart from Asteraceae (including *Elytropappus*, *Eriocephalus, Helichrysum, Oedera, Pteronia* and *Relhania*), other important shrub families represented in renosterveld include Boraginaceae, Fabaceae, Malvaceae, Rosaceae (*Cliffortia*) and Rubiaceae (*Anthospermum*) (Goldblatt & Manning 2002b).

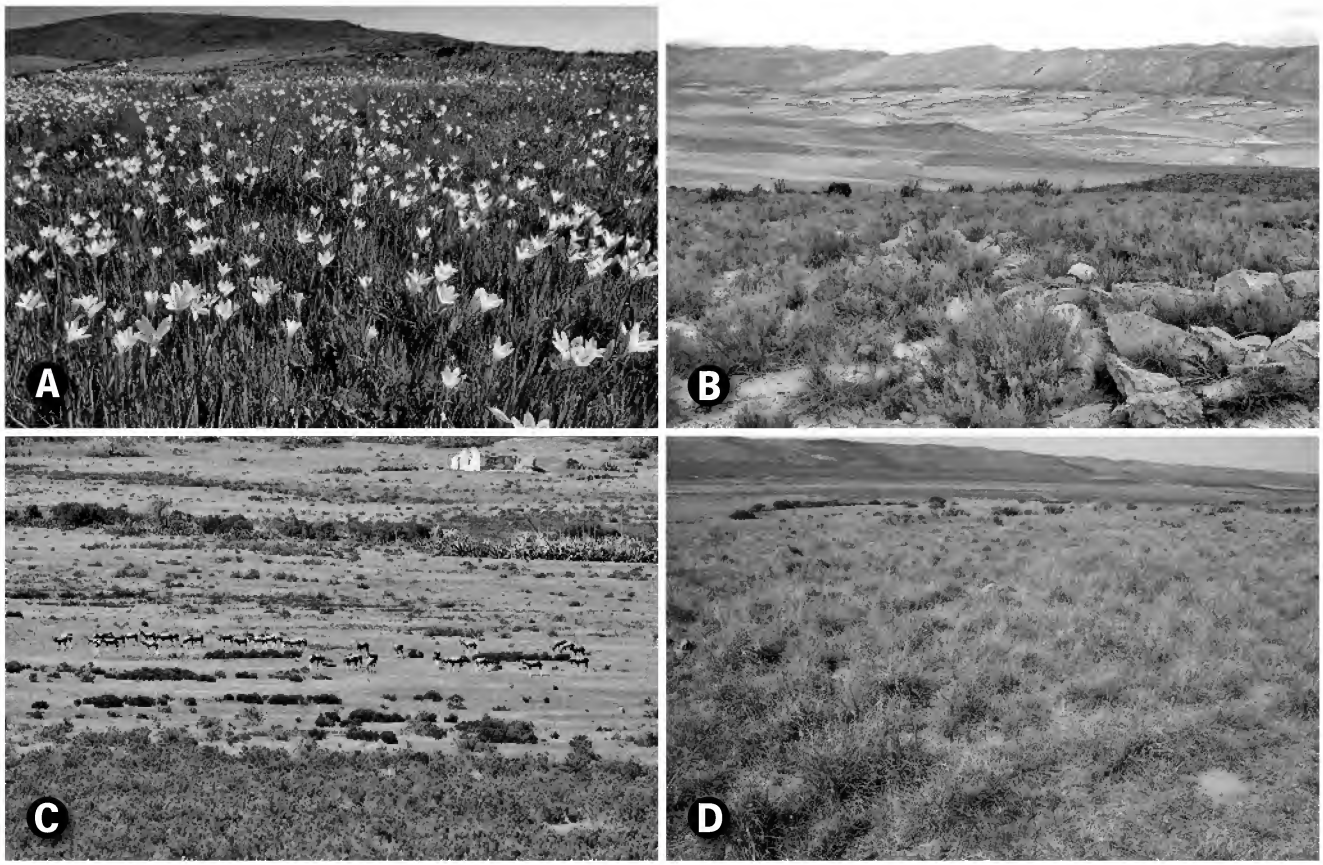

Figure 4.13 Faces of renosterveld: A: 'bulbveld' (bulb-rich herbland) at Waylands near Darling (West Coast) with *Zantedeschia aethiopica, Sparaxis bulbifera* (white), *Geissorhiza radians* (purple and red), *Trachyandra filiformis* (small whitish stars) and a cloud of blue *Heliophila coronopifolia* in the distance; B: typical renosterveld shrubland dominated by renosterbos (*Elytropappus rhinocerotis*) on a slope overlooking the Koo (western Little Karoo); C: extensive grazing lawns in the valley of the Potberg River in the eastern portion of De Hoop Nature Reserve–the major feeding ground of large herds of bontebok *Damaliscus pyrgargus pyrgargus*) and eland (*Taurotragus oryx*); D: tussock grassland with *Cymbopogon pospischilii* and *Themeda triandra* on shale slopes in the Potberg section of De Hoop Nature Reserve. Photographs: A: J.C. Manning, B: L. Mucina, C & D: F.G.T. Radloff.

Among the geophytes are representatives of both the monocots (Amaryllidaceae, Asparagaceae, Asphodelaceae, Iridaceae, Hyacinthaceae, Orchidaceae) and dicots (Oxalidaceae and Geraniaceae) (Duthie 1930, Cowling 1983a, Paterson-Jones 1998, Goldblatt & Manning 2002b, Procheş & Cowling 2004, Procheş et al. 2005, 2006). Indeed the world cut-flower trade owes *Freesia, Ixia, Gladiolus, Ornithogalum* (Chinkerinchee) and *Pelargonium* to plants originally collected from the CFR. The frequency and diversity of geophytes, according to Kruger (1979), increase with that of soil fertility, aridity and fire frequency. Floristic affinities of renosterveld with fynbos are low in spite of their structural similarity (Boucher & Moll 1981). Although many families and genera are shared, apart from geophytes, very few species are shared, with the exception of the shale and granite fynbos types where boundaries are often diffuse.

A major feature of renosterveld, at least the coastal units, is the extensive transformation that has taken place over the last 100 years. Today these areas are predominantly croplands. This follows on a major shift in large herbivore dynamics that took place in the early 18th century, as large game and Khoi cattle herds were replaced by European stock farmers. We will probably never be able to recreate or determine the ecology of renosterveld in any detail (Krug et al. 2004a, b).

Moll et al. (1984) differentiated renosterveld into four distinct (more or less biogeographically defined) types. These exclude the escarpment types, which show strong karroid affiliations.

(1) Renosterveld of the West Coast Centre (west of the Hottentots Holland and Twenty-four River Mountains) tends to have a sparser grass cover, comprising mainly C_3 genera, a higher diversity of deciduous geophytes and annuals, and *Eriocephalus africanus* and *Leysera gnaphaloides* as characteristic subdominants. The overstorey shrubs have a greater canopy cover (50–90%) than in the other centres. Heuweltjies support tall clumps of thicket elements. The unusually high abundance of geophytes is particularly characteristic.

(2) Renosterveld of the South Coast Centre (south of the Langeberg and Riviersonderend Mountains) tends to have less geophytes and more grassy elements (mainly C_4 genera) with typical subdominants *Oedera genistifolia, O. squarrosa* and various species of *Helichrysum* and *Hermannia*. Canopy cover varies from 50–75%. In the east it grades into Albany Thicket types where dissected topography prevents the spread of fire.

(3) Inland renosterveld of the Mountain Centre (from Nieuwoudtville to Oudtshoorn, east of the Cederberg and north of the Langeberg) tends to be more xeric and has a lower cover than the coastal types, but this is determined by moisture; southern aspects may be as dense as in coastal renosterveld types. This renosterveld has a higher proportion of succulents (reflecting a stronger Succulent Karoo influence), and mixtures of renosterbos and *Relhania* as dominants, occasionally with *Pteronia incana*. Total cover is low (25–60%). Grasses (mainly C_4 genera) may be prominent, but are often lost due to overgrazing and may be absent. Locally *Acacia karroo, Euclea undulata* and *Aloe ferox* may be prominent as scattered elements.

(4) Renosterveld of the Eastern Centre is relatively uniform with no emergents above the renosterbos-dominated shrubland. Grasses (mainly C_4 genera) can be a major component, but overgrazing may eliminate them. Renosterveld types of the Eastern Centre have the strongest affinities with Albany Thicket and grasslands to the east. The eastern units of this type are particularly difficult to subdivide.

No further studies on the relationships and determinants of the groupings of Moll et al. (1984) have been undertaken. Despite its structural diversity, renosterveld has so far not been subject to detailed vegetation-structural classification. However four major structural types have been used in an informal way: shrubland, tussock grassland, grazing lawn (low, heavily grazed grasslands), and lately also herblands dominated by bulbous plants ('bulblands') (Figure 4.13).

3.3 *Western Strandveld*

Strandveld (Figure 4.14) consists of communities of medium dense to closed (sometimes forming an impenetrable tangle) shrublands dominated by sclerophyllous, broad-leaved shrubs (Moll et al. 1984). Along arid stretches (especially at the West Coast) the succulent shrubby element becomes obvious. The shrublands are very low, especially closer to the seashore, but can grow tall in sheltered sites and become replaced by low scrub milkwood forest (especially on the Agulhas Plain; see Cowling et al. 1988). Structural and floristic differences between strandveld and neighbouring fynbos are striking. Although restios (*Ischyrolepis, Thamnochortus, Willdenowia*) can be a common element on deep soils, the Proteaceae are absent and Ericaceae are extremely rare.

Strandveld vegetation is usually found close to the sea (whence the Afrikaans term 'strandveld' or 'beach vegetation') but never in habitats under direct influence of sea spray and other factors associated with the influence of the sea water—these habitats are occupied by the azonal coastal vegetation (see Chapter 14). Immediate coastal hinterland with its stabilised Pleistocene (rarely also post-Holocene) dune cordons showing signs of soil formation is the characteristic habitat of the typical strandveld vegetation of the southwestern and southern Cape. In the coastal hinterland, strandveld also occurs on harder substrates supporting shallow soils, such as on granites (surrounds of Vredenburg, Saldanha and further south in Cape Town on the West Coast and on the coast south of George and Knysna on the South Coast), Tertiary limestones of the West Coast (Langebaan area) and South Coast (from De Kelders to as far as Mossel Bay). Strandveld penetrates deep inland in several localities, such as east of Langebaan and Saldanha (here found over sandy overlying calcrete pavements), along limestone krantzes (cliffs) fringing De Hoop Vlei and in the hinterland of the sedimented portion of Mossel Bay.

As opposed to the sand fynbos (often bordering on the strandveld units, both on the West and South Coasts), the substrate of the strandveld is mineral-rich, with high concentrations of calcium. Intricate relationships between topography, local waterlogging and fire dictate the nature of the delimitation of strandveld and sand fynbos on calcium-rich coastal sands of the South Coast (see Section 9.1.3 on sand fynbos below for further details).

Unlike in fynbos or renosterveld, fire plays a lesser role in the strandveld communities. Despite high cover of the strandveld shrublands, fire frequency is low. However, the succulent nature of strandveld impedes the spread of fire, except under exceptional conditions. Although no data on fire-return intervals for strandveld exist, they are probably in the order to 50–200 years. The early seral stages following fire are dominated by Restionaceae and Rutaceae and have a typical fynbos physiognomy, hence the term 'dune fynbos'. It takes dune fynbos over 20 years before it becomes overtopped by more typical strandveld elements.

The major floristic component of the strandveld communities, especially on the South Coast, shows subtropical biogeographi-

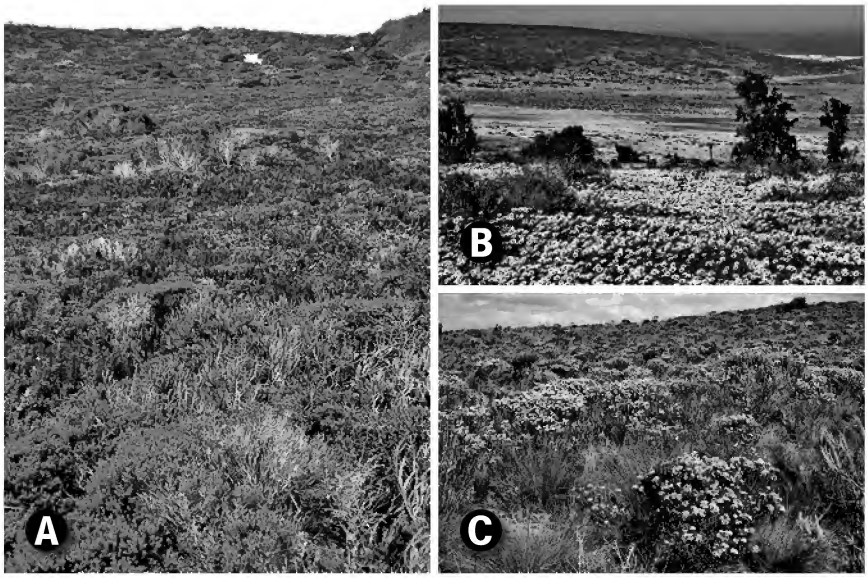

Figure 4.14 Faces of strandveld. A: coastal dune strandveld dominated by aromatic shrubs (buchus) such as *Acmadenia mundiana* and *Agathosma collina* and the restio *Ischyrolepis eleocharis* in De Hoop Nature Reserve (Overberg); B: granite strandveld with spring flower display (*Dimorphotheca pluvialis*) in the Postberg Reserve (West Coast National Park); C: typical dune strandveld with *Metalasia muricata* in De Mond Nature Reserve near Struisbaai. Photographs by L. Mucina.

cal links. The notable genera occurring in strandveld and pointing towards this (sub)tropical link include for example *Aloe, Azima*, *Cassine, Clausena, Cussonia, Euclea, Diospyros, Grewia, Gymnosporia, Lauridia, Maytenus, Mystroxylon, Pterocelastrus, Rhus, Robsonodendron, Sideroxylon* and *Tarchonanthus*. The strandveld units of the West Coast also show a link to the Succulent Karoo (through the increased occurrence of succulent shrubs of genera such as *Antimima, Cheiridopsis, Cotyledon, Crassula, Dorotheanthus, Drosanthemum, Euphorbia, Mesembryanthemum, Prenia, Ruschia, Tetragonia, Tylecodon, Zygophyllum* etc.). Floristic links to the fynbos and renosterveld (especially the granite renosterveld) are indicated by the occurrence of genera such as *Aspalathus, Babiana, Ehrharta, Ischyrolepis, Metalasia, Oscularia, Oxalis, Phylica, Psoralea, Romulea, Thamnochortus, Thesium, Ursinia* and *Willdenowia*. (For discussion on possible routes of evolution of the strandveld flora, see Section 5.2 below.)

The dune thicket flora represents a westward extension of the subtropical flora into the warm-temperate southern and Western Cape. It is one of the major reasons why Tinley (in Heydoorn & Tinley 1980; see also Moll et al. 1984) extended the concept of 'thicket' to the Western Cape strandveld thickets and why the vegetation map by Low & Rebelo (1996) included the coastal thickets of the Western Cape in the (subtropical) Albany Thicket Biome. The clear 'depauperization' trend in representation of the subtropical element in the dune thicket flora was reported by Cowling & Pierce (1985), who found that of 72 thicket species occurring at Cape St Francis, 56 (hence 79%) were found in the Mossel Bay and Riversdale regions, but only 38 species (52%) in the southwestern Cape.

An interesting phenomenon linked to the dune thicket vegetation of the strandveld complex is the change in growth form in some typically subtropical woody elements. *Sideroxylon inerme* can be a tall tree reaching a height of 15 m in the tropics (and still with a tree stature in dune forest along the KwaZulu-Natal coast), becoming only a low tree or shrub (even showing a creeping habit) on the temperate dunes of the southwestern Cape. This remarkable plasticity has also been observed in *Pterocelastrus tricuspidatus, Maytenus procumbens* and *Cassine peragua* (Cowling & Pierce 1985, Taylor & Boucher 1993).

Here we consider the strandveld units FS 1–9 as intrazonal units of the Fynbos Biome, since their extent is strictly linked to that of the Fynbos Biome—the zonal fynbos units form the inland backdrop to the coastal-bound strandveld units. Hence the strandveld units share the basic feature of the macroclimate with the neighbouring zonal fynbos units. We call this group of strandveld units 'Western Strandveld' to distinguish them from those fringing our coasts further east (in the realms of the Albany Thicket Biome and Indian Ocean Coastal Belt). The latter have been handled as azonal (AZs 1–3) and featured in Chapter 14.

Moll et al. (1984) recognised two types within strandveld, namely 'West Coast Strandveld' and 'South Coast Strandveld'. Our current classification builds upon this dichotomy (largely motivated by the differences in growth-form composition) and pursues further subdivision based on regional/local bioclimatic and biogeographical patterns as well as geology (reflected in the separation of the limestone and granite strandveld units).

3.4 Fynbos Thicket

While the strandveld shrublands are linked to coastal (hinterland) habitats, the fynbos thickets are found in fire-sheltered habitats (Figure 4.15) embedded as fragments within fynbos—sandstone, quartzite and granite fynbos, in particular.

We consider 'fynbos thicket' a distinct (from subtropical Albany Thicket, from fynbos *per se*, from riparian thickets typical of the Fynbos Biome as well as from afrotemperate forests) vegetation type characterised by dominant sclerophyllous ('other than nanophyllous' sensu Campbell 1985) shrubs and small trees found in fire-sheltered habitats such as steep rocky slopes, boulder formations, screes and deep kloofs without streams, and embedded within the fire-prone matrix of typical fynbos. The understorey of these small shrublands is sparse. Most importantly, the dominant shrub elements are recruited from taxa with their evolutionary roots (and current centres of diversification) in the (sub)tropics—suggesting 'pre-fynbos' age, hence possibly being relicts of pre-Pliocene subtropical woodlands that possibly dominated the landscapes of the southwestern Cape.

The fynbos thickets have never been a subject of an exclusive scientific enquiry. Many authors have, however, described their local communities but usually focusing on fynbos or forests (e.g. McKenzie et al. 1977, Laidler et al. 1978, Kruger 1979, Taylor 1984b, 1996, Van Wilgen & Kruger 1985, McDonald 1988, Mustart et al. 1993, Cleaver et al. 2005). So far, the most penetrating insight has been provided by structure-oriented studies of Campbell (1985). This author described two structural variations of the fynbos thickets called Cape and Mitchell Thickets. Cowling & Holmes (1992b) introduced an overarching term 'Western Thicket' to encompass both.

In deep kloofs on lower northern sandstone slopes, fynbos thickets with species of *Buddleya, Rhus, Salvia* and *Pelargonium* occur in fire-safe habitats. These are dominated by aromatic-leaved species, unusual in fynbos, perhaps an adaptation

against grazing by animals on their way to summer watering points up the kloofs. They have never been studied ecologically or floristically.

Clumps of the wild olive (*Olea europaea* subsp. *africana*) occurring within renosterveld matrix on rocky outcrops or on termitaria (Boucher 1980) also qualify as patches of 'fynbos thicket'.

The question arises whether thicket patches found within fynbos matrix should rather be considered forest (Afrotemperate Forest Biome) or a Fynbos Biome type. Both may have Restionaceae and other typical fynbos elements as an understorey, in which case they should be considered as 'thicket fynbos'. In these cases the understorey usually burns. In granite fynbos, granite boulders often shelter stands of 'closed-scrub fynbos' and 'thicket fynbos'. Presumably on richer soils the forest elements establish more easily by virtue of the richer soils. However, these patches appear to be far more dynamic, often containing restioid, ericoid and proteoid elements, or patches of typical fynbos within them. Furthermore, the boundaries are far more diffuse. These species are not confined to these small forest habitats, but may occur as isolated plants in fynbos in fire-safe areas, some as small as single large rocks. Most of these species fail the test as 'true forest species' in that they can establish and survive in fynbos vegetation. They are forest pioneer elements, most of which disappear as the forest matures to afrotemperate forest and are more at home in the fynbos landscape than in forest.

Due to the very limited extent of patches of fynbos thicket and virtually no floristic data to address possible subdivision, this type was not mapped and subsumed into the fynbos units in which they occur. We have, however, noted the 'fynbos thicket' elements in the species lists in the descriptions of fynbos vegetation units (Table 4.2).

3.5 *The Within-biome Boundaries*

Fynbos and Renosterveld

Renosterveld occurs predominantly on clay-rich soils. At drier extremes (usually below 250–300 mm) it is replaced by succulent karoo shrublands, and in wetter areas (usually over 500–800 mm) by fynbos (Cowling & Holmes 1992b). This boundary is not determined by fire, as both communities are dominated by fire, although renosterveld (at least in higher-rainfall areas) typically burns more frequently (3–5 years) than fynbos (10–25 years) because of faster growth rates and dominance by finer fuel grasses. By our definition, the boundary is where Restionaceae stop (or drop to less than 5% cover), usually in mesotrophic asteraceous or graminoid fynbos, but typically Ericaceae and Proteaceae end at these boundaries as well. However, transition zones are broad and diffuse, resulting in different interpretations of the actual renosterveld-fynbos boundary. This transition has been attributed to leaching and consequent loss of soil nutrients supporting fynbos (Cowling & Holmes 1992b).

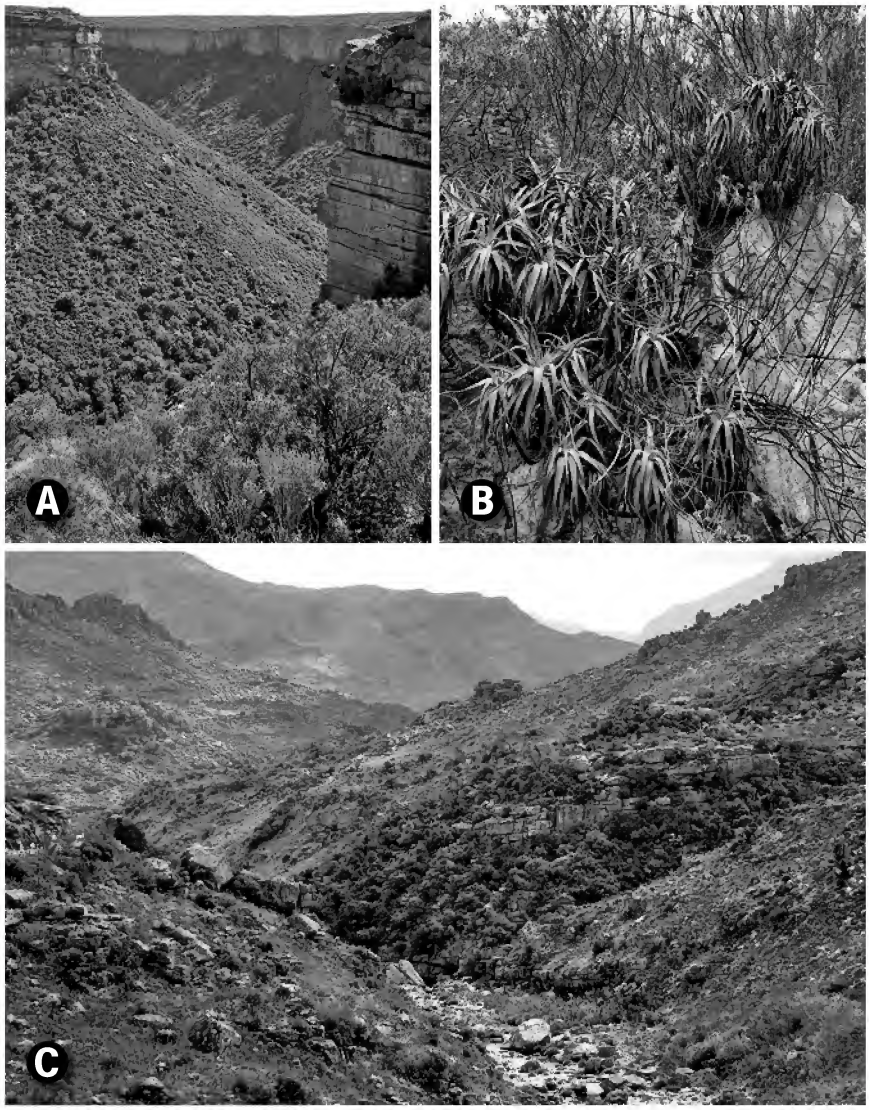

Figure 4.15 Faces of Cape (fynbos) thicket. A: steep slopes of the Oorlogskloof River canyon cutting though the Bokkeveld Plateau, clad in fire-resistant thicket; B: a thicket group with *Aloe arborescens* in the mouth of the Baviaanskloof Valley near Genadendal that survived a recent fire; C: Cape thicket with *Heeria argentea* on rocky slopes of the Witrivier in the Bain's Kloof Pass near Wellington. Photographs by L. Mucina.

The fynbos-renosterveld transition appears related to differences in leaching and is determined by annual precipitation but it is unaffected by seasonality of rainfall. Renosterveld does not typically occur on sandstone and quartzite, but occasionally occurs in more arid facies where a thin clay or silt layer, usually derived from remnants of overlying shale, covers the bedrock. Even skeletal layers of clay appear to exclude Restionaceae and most other fynbos taxa. Typically this only occurs in asteraceous fynbos; as in other fynbos types, the clays would be sufficiently leached to allow fynbos to occur.

Overgrazing and excessive burning may convert fynbos to renosterveld on shales, but the mechanism for this is unclear. Bush-cutting and liming of graminoid fynbos in the Langeberg foothills convert it to a grassland or grassy shrubland that, because of the preferential loss of typical fynbos elements, would be classified as renosterveld (A.G. Rebelo, unpublished data).

Table 4.2 Floristic composition of the fynbos thicket communities embedded within various fynbos units (FFs 1 Bokkeveld Sandstone Fynbos, FFs 4 Cederberg S.F., FFs 10 Hawequas S.F., FFs 9 Peninsula S.F., FFg 2 Boland Granite Fynbos, FFg 3 Peninsula G.F., FFs 25 North Kammanassie S.F.). Status: [A]found in both western and eastern fynbos thickets, [Be]presumably endemic to fynbos thickets of the Bokkeveld, [C]typical of coastal-close fynbos thickets of the Cape Peninsula, [Ce]presumably endemic to fynbos thickets of the Cederberg, [E]only in eastern thickets, [Ge]presumably endemic to granite fynbos thickets, [He]presumably endemic of the fynbos thickets of the Hawequas Mountains, [W]only in western thickets. The entries (numbers) within the body of the table refer to the sources of the data: 1: L. Mucina (unpublished data), 2: Taylor (1996; original taxon names: **Protasparagus*, ***Myrsiphyllum*, ****Colpoon*, [#]*Cassine barbara*, [&]*E. natalensis*, [+]*L. lobata*), 3: Mustart et al. (1993; **Protasparagus*, [#]*Cassine barbara*, [&]*E. natalensis*, [+]*L. lobata*, [%]*G. heterophylla*), 4: Taylor (1983; **T. camphoratus*, ***Colpoon*, [$]*Cassine barbara*, [%]*G. heterophylla*), 5: McKenzie et al. (1977; **Cassine capensis*), 6: Van Wilgen & Kruger (1985; **O. europaea*, **probably *R. scytophylla*, [$]*A. thunbergianus*), 7: McDonald (1988 ; **Protasparagus compactus*), 8: Cleaver et al. (2005; * *Cassine eucleiformis*, [&]*E. natalensis*), 9: A.G. Rebelo & N. Helme (unpublished data; see the descriptions of the respective units in this Chapter), 10: PRECIS database.

Taxon	Status	FFs 1	FFs 4	FFs 10	FFs 9	FFg 2	FFg 3	FFs 25
Hyaenanche globosa	Be	1, 10						
Clivia mirabilis	Be	1						
Lidbeckia quinqueloba	Ce		2+,3+					
Aloe plicatilis	He			6				
Chionanthus foveolatus	C				4			
Cussonia thyrsiflora	C				4			
Cynanchum obtusifolium	C				4			
Euclea racemosa	C				4			
Maurocenia frangularia	C				4			
Olea exasperata	C				4			
Phylica buxifolia	C				4			
Pterocelastrus tricuspidatus	C				4			
Rhus glauca	C				4			
Rhus laevigata	C				4			
Sideroxylon inerme	C				4			
Tarchonanthus littoralis	C				4*			
Clutia pterogona	Ge					5	10	
Leucadendron argenteum	Ge					5	1	
Cotyledon woodii	E							8
Cussonia paniculata	E							8
Diospyros lycioides	E							8
Euclea crispa	E							8
Euclea natalensis subsp. *natalensis*	E							8&
Euclea polyandra	E							8
Euclea undulata	E							9
Ficus burtt-davyi	E							8
Lachnostylis bilocularis	E							8
Melianthus comosus	E							8
Pelargonium zonale	E							8
Rhus pallens	E							9
Robsonodendron eucleiforme	E							8*
Maytenus acuminata	A	10	10	9	10	10	7	10
Maytenus oleoides	A	9	2,3	6		5		8
Clutia alaternoides	A	10	10	10	10			8
Dodonaea viscosa	A	1	2,3	10	10			8
Gymnosporia buxifolia	A	10	3%		4%	10		8
Myrsine africana	A	10	2,3	6	4	5	10	8
Rhus tomentosa	A	3	2,3	6	4	5	7	9
Olea europaea subsp. *africana*	A	1	2,3	6*			7	8
Osyris compressa	A		2***		4**			8
Pteridium aquilinum	A			1		5	7	8
Solanum tomentosum	A		2					8
Diospyros glabra	W	10	2,3	6	10	5	7	
Halleria lucida	W	10	10	10		10	7	
Cassine schinoides	W	10	2	6			7	
Viscum pauciflorum	W	10	2				10	

Taxon	Status	FFs 1	FFs 4	FFs 10	FFs 9	FFg 2	FFg 3	FFs 25
Chironia baccifera	W		2,3	6		5	7	
Rhus rosmarinifolia	W		9				7	
Cassine peragua subsp. *peragua*	W	10	2#,3#	10	4$	5*		
Clutia pulchella	W	10	2			10		
Kiggelaria africana	W	10	2,3	10		5		
Knowltonia capensis	W		3	6	4	5		
Heeria argentea	W	1,10	1,2,3	6	10			
Podocarpus elongatus	W	1, 10	2,3	1, 10	1			
Indigofera frutescens	W	10	2,3	10				
Clutia polifolia	W	10	2	10				
Anisodontea bryoniifolia	W	10	2					
Diospyros austro-africana	W	10	2,3					
Euclea acutifolia	W	10	2,3					
Euclea lancea	W	9	2					
Euclea linearis	W	10	3					
Euclea natalensis subsp. *capensis*	W	9	2&,3&					
Euclea tomentosa	W	1,10	1,10					
Rhus scytophylla	W		2,3	6**				
Rhus undulata	W		2,3	6				
Secamone alpini	W		2,3	6				
Othonna amplexifolia	W		2,3	6				
Pellaea pteroides	W		2	6				
Ficinia acuminata	W		2,3	6				
Asparagus scandens	W		3*		1			
Asparagus rubicundus	W			6$	1			
Rhus lucida	W			9	4	5		
Widdringtonia nodiflora	W			1		5		
Olea capensis subsp. *capensis*	W				4	5		
Rapanea melanophloeos	W				10		7	
Tylecodon paniculatus	W	1,9						
Melianthus major	W		2					
Rhus dissecta	W		2,3					
Rhus rimosa	W		2,3					
Senecio vestitus	W		2					
Asparagus aethiopicus	W		2*					
Asparagus kraussianus	W		2**					
Asparagus retrofractus	W		2*					
Asparagus suaveolens	W		2*					
Crassula atropurpurea	W		2					
Crassula decumbens	W		2					
Crassula umbella	W		1,2					
Knowltonia vesicaria	W		2					
Stachys aethiopica	W		2					
Teedia lucida	W			6				
Ursinia abrotanifolia	W			6				
Asparagus asparagoides	W			6				
Asplenium aethiopicum	W			6				
Crassula albiflora	W			6				
Crassula coccinea	W			6				
Mohria caffrorum	W			6				
Rhus angustifolia	W						7	
Asparagus lignosus	W						7*	

Fynbos and Strandveld

Like the fynbos boundaries with the Karoo and Albany Thicket Biomes, the boundary between fynbos and strandveld is largely determined by fire dynamics. Thus sand fynbos tends to occur adjacent to strandveld, with the boundary and its transition zones determined by the interplay of topography (primarily dunes) and succulence associated with more nutrients derived from salt spray from the sea. A dune fynbos occurs as a seral stage to strandveld in areas of intermediate fire. The details of the sand fynbos/strandveld boundary are summarised under sand fynbos.

Renosterveld and Strandveld

Renosterveld does not abut upon strandveld. The two types occur on different soil types and typically the aeolian sand/shale interface is with acid sands supporting sand fynbos rather than strandveld.

4. Evolutionary and Ecological Driving Forces

Four complex factors stand paramount in fynbos ecology, which, taken together, separate the Fynbos Biome from the other biomes of southern Africa. These are: (1) the nutrient-poor soils supporting fynbos, arranged in an archipelago within more nutrient-rich soils containing mainly renosterveld, (2) hot, dry summers alternating with cool, wet winters, typical of other mediterranean-type regions, at least in the west of the biome, (3) recurrent fires at 5–50-year intervals in fynbos and 2–10 years in renosterveld (not nearly annual as in the Grassland and Savanna Biomes, or absent as in the Karoo biomes), and (4) an intricate complex of animal-plant interactions, especially involving grazing, pollination and dispersal (see also Goldblatt & Manning 2002b, Linder 2003, Barraclough 2006).

We do not cover the considerable amount of other information on plant function and ecophysiology in the Fynbos Biome here. Reviews in these fields include those of Lamont (1982), Mooney et al. (1982), Rutherford (1991), Stock & Allsopp (1992), Stock et al. (1992b, 1997).

4.1 Responses to Low Nutrients

The generally nutrient-poor soils of the fynbos proper pose a serious ecological challenge to plants. The significance of the nutrient-poor soils in the Fynbos Biome is overwhelming. Although there is obviously an interplay between fire, climate and biotic interactions, the unique and diverse systems prevalent in fynbos are unsurpassed in all other ecosystems on the subcontinent, and indeed in the world. By contrast, renosterveld and strandveld do not appear to be uniquely unusual in any traits. It is highly likely that further surprises await ecological investigators as ecophysiological and genetic investigations into low-nutrient adaptations progress.

Plants have come up with a number of intriguing answers leading to the evolution of traits of eco-morphological, life-historical and community-assembly rules. Some of the most prominent ecological-evolutionary traits identified that link the composition and dynamics of fynbos to a low soil nutrient status are listed below.

Serotiny: The phenomenon of serotiny (bradyspory) is confined to fynbos vegetation within the Fynbos Biome. It is absent in renosterveld which burns too frequently, and as a fire-related phenomenon it is largely absent in other biomes. In this strategy, species retain the seeds in fire-proof seedheads on the plant and only release them after a fire. This strategy requires thick stems (ca. 10 mm at the flowerhead) to remain standing after the fire and is therefore largely confined to emergent and overstorey plants (where fires are also cooler), and a few resprouters. Serotiny requires predictable fire-return times at greater than 5-year fire intervals—it is thus rare in grassy fynbos. As a strategy elsewhere it is virtually confined to mediterranean-type ecosystems on nutrient-poor soils (Bond 1985) and coniferous forests. It is sparse in communities too dry (especially asteraceous fynbos, or seasonally dry restioid fynbos) or too cool (especially ericaceous fynbos, where it is most prominent in resprouters) to allow growth of thick stems. It occurs in Proteaceae (*Protea, Leucadendron, Aulax*), Bruniaceae (*Brunia, Berzelia, Nebelia*), Ericaceae (*Erica sessiliflora*), Asteraceae (*Phaenocoma*) and Cupressaceae (*Widdringtonia*), totalling just over 100 species. Alien invaders displaying serotiny include species of *Hakea, Banksia* (both Proteaceae), *Pinus* (Pinaceae), *Callistemon* (Myrtaceae) and *Casuarina* (Casuarinaceae). Seed protection in fynbos species (cones and seedheads) is not as robust as in the heathlands of Australia, where there is a parrot seed predator capable of extracting seeds from fire-proof cones. Seed germination cues are simple, usually requiring cool conditions and saturated soils (Le Maitre & Midgley 1992).

Because seeds are exposed to predation after release following a fire, nonseasonal fires (spring or early summer in the summer-drought region, and winter and summer in the all-year rainfall region) may decimate post-fire recruitment (S. Heelemann, personal communication), presumably by prolonging the period between release and germination. Non-resprouting serotinous species may be eliminated by fire in young veld (less than 3–8 years of age, depending on species) where plants have not yet set seed—as all the plants typically burn, no reserve seed bank is possible, as with soil-stored seed banks. This feature is used to control serotinous alien invaders: adults are hacked and after seed release the veld is burned, thereby eliminating the species (Le Maitre & Midgley 1992). Serotinous species also exhibit senescence, in which plants become moribund, lose their seed banks, and die out when veld exceeds 2–3 times the average fire cycle in age (Le Maitre & Midgley 1992).

Myrmecochory: Ant seed dispersal is found in 15% of fynbos species (Bond & Slingsby 1983, 1984, Breytenbach 1988, Bond et al. 1990, 1991, Johnson 1992, Cowling et al. 1994b), of almost all characteristic and dominant plant families (although it is very rare in Ericaceae), and in all growth forms. In many cases, wind-dispersed species in neighbouring vegetation types have myrmecochorous congeners in fynbos (Bond & Slingsby 1983, Bond et al. 1991). These species tend to produce small or large nuts with an ant-fruit or elaiosome. The fruit are buried by indigenous ants in their nests, where they remain dormant until after a fire. The alien Argentine Ant (*Linepithema humile*) consumes the elaiosome above ground and does not bury the seed, resulting in high predation (Bond & Slingsby 1984, Christian 2001, Christian & Stanton 2004, Witt et al. 2004, Witt & Giliomee 2004, Traveset & Richardson 2006). Post-fire germination cues are complex and are determined by fire effects, cyclical soil temperature fluctuations and maturation requirements. Burial removes fruit from rodent and bird predation, and from fire and probably provides protection against fungi, especially *Phytophthora*. Myrmecochorous species are seldom dominants, but they may account for a high cover in the middle strata, and for up to 30% of species in a community.

Apart from a paucity in dry asteraceous fynbos, and low cover in restioid fynbos, myrmecochory has no obvious overall patterns between fynbos communities. Some alien invasive Fabaceae (*Acacia*) are myrmecochorous. Seed-dispersing ants include

deep buriers (> 50 mm deep), large ants that disperse the larger fruit, and smaller ants with shallow burial sites (10–50 mm) that are unable to move the larger fruit (Le Maitre & Midgley 1992). Myrmecochory is almost nonexistent in renosterveld and adjacent biomes, and is usually attributed to the need to rapidly store seeds in predator-free, fire-safe refugia (Le Maitre & Midgley 1992).

In total contrast to the prevalence of myrmecochory, is the near total absence of ornithochory (seed dispersal by birds) in fynbos. Frugivorous birds are generally absent from fynbos, the red-winged starling (*Onychognathus morio*) being the notable exception. Fleshy fruit are confined to the aerial parasites *Cassytha* (Lauraceae) and *Viscum* (Viscaceae), the root parasite *Osyris* (Santalaceae) and the fynbos endemic family Grubbiaceae. By contrast, ornithochory is a prominent dispersal strategy in strandveld, subtropical thickets and in forests, which all contain abundant and diverse fauna of frugivorous birds (Le Maitre & Midgley 1992).

Obligate Reseeding versus Resprouting: Fynbos is unusual in the low proportion of woody plants that survive fire by resprouting. Both renosterveld (which burns more frequently) and forest (which hardly ever burns) are characterised by resprouting plants. Similarly, both the Grassland and Savanna Biomes are dominated by resprouters. Because of the predictable fire-return interval, fynbos shrubs appear to invest all their resources in seed production at the expense of regeneration. These species dominate fynbos in terms of cover and comprise most emergent elements. The only true fynbos shrub that is able to regenerate from aerial stems (epicormic resprouter) is the waboom, *Protea nitida*, which occurs on richer, colluvial substrata. In forest, savanna and grassland, epicormic resprouting is the norm.

Obligate reseeders occur in all plant families and comprise most species of the Ericaceae (> 90%), Proteaceae (> 80%), Fabaceae (> 75%), Asteraceae, Rutaceae and Bruniaceae, and is even common in the Restionaceae, in which it has been underestimated in the past (Le Maitre & Midgley 1992). In a study of 10 fynbos species 26 years after a fire at Jonkershoek near Stellenbosch, the ratio between root and shoot mass was lower (0.2) in the obligate reseeders than in the resprouters (2.3) (Higgins et al. 1987, Smith & Higgins 1990). Resprouters can persist at a site through several generations of obligate reseeders (Bond & Midgley 2003). By contrast, reseeders outgrow resprouters, and after 15 years start shading out and reducing the cover of resprouters, resulting in increased species richness in areas dominated by reseeders compared to resprouters (J.H.J. Vlok, personal communication).

Lack of Annuals: Annuals are generally a rare component of fynbos communities, especially when compared to other mediterranean regions (Naveh & Whittaker 1979, Cowling 1983a). Wisheu et al. (2000) attribute the virtual absence of annuals in fynbos to the infertile soils and hypothesise that the soil nutrient status is too low for annuals to complete their life cycles and set seeds in one growing season.

Most annuals in the Fynbos Biome occur in strandveld (especially on granite), some types of renosterveld (especially the dolerite and granite types), sand fynbos and asteraceous fynbos in the more arid facies. By contrast, annuals are prominent in the succulent karoo shrublands. Alien annuals are prominent only along paths in most fynbos types (Vlok 1988). However, alien annuals have become invasive in sand fynbos and renosterveld, where they appear to displace the geophytes (Le Maitre & Midgley 1992).

The lack of fire annuals in fynbos compared to more nutrient-rich renosterveld types is particularly marked. Most early seral species in fynbos live for 3–5 years. Some orchids and bulbs flower only in the year following a fire, but, being geophytic, probably live through several fire cycles.

Sclerophylly: Sclerophylly is a feature of most mediterranean floras and may be a summer-drought strategy. However, it is especially prominent in systems where low nutrients limit the option of drought deciduousness, and long-lived, tough, low-nutrient leaves capable of resisting desiccation are required. The lack of nutrients results in a carbon-rich, and thus woody, sclerophyllous leaf. This effectively eliminates herbivory (the nitrogen-to-carbon ratio is too low to allow animal utilisation, except in young growth). As a consequence, defences against herbivory (thorns, spikes, leaf chemicals) are largely absent in fynbos. In fynbos sclerophylly is manifested as proteoid, ericoid, restioid and spine-tipped leaf forms (Le Maitre & Midgley 1992). On richer soils—bearing strandveld and renosterveld—succulent, orthophyllous and drought-deciduous leaves abound, often protected with thorns, spines and aromatic compounds.

Lack of Mycorrhiza and the Presence of Cluster Roots: Two of the dominant components in fynbos, the Proteaceae and the Restionaceae and Cyperaceae, are characterised by not having fungal associates to extract nutrients from the soil. Instead they have, respectively, proteoid and caudiform rootlets, which resemble dense balls or carrots of fine root hairs (Lamont 2003). These cluster roots form a large surface area releasing phosphate-solubilising compounds and efficiently extracting phosphates in a small soil volume (Lambers et al. 2003). Fertilising with phosphorous or potassium kills the plants and on richer soils these rootlets are not produced. It has been argued that because fungi have nitrogen-rich cell walls they are a liability in nutrient-poor fynbos soils and species utilising them are compromised and never attain emergent dominance, except under special conditions as for instance in Ericaceae with endorhizal mycorrhiza under peaty conditions. However, even then Ericaceae are spindly plants lacking the robustness of the other characteristic dominants (Le Maitre & Midgley 1992). Cluster roots are apparently not prevalent in renosterveld or strandveld.

Carnivory and Digestive Mutualism: Because of the nutrient-poor soils, and especially peaty soils, it is not surprising that carnivorous plants abound, although they are never dominant. Over 10% of the world's species of *Drosera* (15 species) occur in fynbos. Of the other typical plant carnivores, the genus *Utricularia* is also represented in fynbos wetlands (Le Maitre & Midgley 1992). The shrubby endemic family Roridulaceae (two species) superficially resembles *Drosera*, but plants do not digest trapped insects, utilising heteropterans and spiders to process nutrients (Ellis & Midgley 1996, Anderson & Midgley 2002, 2003, Anderson et al. 2004). The pitcher type of carnivorous plant is absent from fynbos (Le Maitre & Midgley 1992).

Low Biomass of Herbivores: The low nutrient status of fynbos makes the soils unsuitable for agriculture, although with modern methods of fertilisation via watering this is no longer true. A characteristic of fynbos is the low number and biomass of animals, especially large animals, but also birds and insects, encountered. Carrying capacity for fynbos is generally lower than 1 small stock unit per 8 ha (Stock et al. 1992b). Although large mammals were generally absent, in the past fynbos was probably well traversed by large animals en route to kloof and high-altitude seeps as a water source during the dry periods, and as migration routes between different renosterveld and karroid shrublands. Use of fynbos by large mammals for food was probably limited to early post-fire regrowth. The absence of antiherbivore defence (both structural and chemical) in fynbos

plants is striking (Le Maitre & Midgley 1992). Old kraals and historical bomas have distinct and often well-defined ruderal plant communities, as do dung middens of klipspringer and vaal rhebuck, the largest extant herbivores in fynbos proper today. Mountain zebra tend to frequent shale bands and renosterveld where they have access to these. While biomass of herbivores (and consequently carnivores) is very low, animal diversity is high, especially among insects (Le Maitre & Midgley 1992). The fynbos insect fauna is particularly poorly known, but freshwater, cave and forest faunas are particularly rich in species and endemics. Of the six birds endemic to fynbos, two specialise on seeds and two on insects, and two are nectarivores (Stock et al. 1992b). (The significance of large-mammal herbivory in renosterveld is discussed in Section 4.4.1 below.)

Bird and Mammal Pollination: One of the most striking features of fynbos on nutrient-poor soils is the contrast between the low biomass of herbivores, insectivores and frugivores, and the relative abundance and conspicuousness of nectarivorous birds. The same is true of the plants: bird-pollinated species are conspicuous, abundant and usually dominant (both in cover and structure) in their communities, especially so in proteoid and ericaceous fynbos. This is unparalleled in renosterveld, strandveld, karoo, thicket or forest. Although not so obvious amongst the mammals, mammal-pollinated plants are also abundant and often dominant in terms of cover.

Ornithophily (bird pollination) is most common in fynbos, with 75% of bird-pollinated plant species on the subcontinent occurring in fynbos (Rebelo 1987a). Approximately 5% of fynbos plant taxa are pollinated by birds (Johnson 1992). Nectarivorous birds account for 50% of bird biomass in fynbos, but less than 5% in other vegetation types (Rebelo et al. 1984). Bird-pollinated taxa are concentrated in the Ericaceae (ca. 100 species), Proteaceae (ca. 80 species, especially in *Leucospermum, Mimetes, Protea*) and in geophytes of Amaryllidaceae and Iridaceae (Rebelo et al. 1984, Johnson 1992, Goldblatt et al. 1999), but are also found in Orchidaceae (Johnson 1996a). Although nectarivore diversity is similar to other ecosystems, bird-pollination systems in fynbos show a striking asymmetry, with several hundred plant taxa relying on only 3–5 bird species for their pollination. Two key pollinators, the Cape Sugarbird (*Promerops cafer*) (primarily visiting Proteaceae) and Orange-breasted Sunbird (*Anthobaphes violacea*), primarily visiting *Erica*, are endemic to fynbos. The other significant bird pollinator in fynbos is the Malachite Sunbird, which has been suggested to specialise on geophytes, although it regularly visits other plants as well (Rebelo 1987a).

Plants pollinated by birds invariably exhibit a classic syndrome of tubular or brush-like flowers, or cup-shaped flowerheads with copious amounts of dilute nectar and an absence of discernable scent. Colour, however, does not conform to the classical syndrome, with numerous pale and even green flowers: in fact, most bird-pollinated species are strongly colour polymorphic in fynbos (Rebelo 1987a). The high prevalence of ornithophily is ascribed to a high energy resource, but lack of nutrients to convert this to nonstructural tissue. Ornithophilous nectar is also dilute and abundant, requiring water. It is rare in the drier types (asteraceous and restioid fynbos), but dominates proteoid fynbos, and is prominent in ericaceous fynbos. Flowering tends to peak in winter and spring, depending on the availability of moisture. Seasonal movements of birds within fynbos are unknown (Rebelo 1987b).

Therophily (pollination by nonflying mammals) in shrubby plants is confined to fynbos in *Protea* (with over 20 species) and *Leucospermum* (two species) (Rebelo & Breytenbach 1987). Pollination by rodents is associated with a distinctive floral syndrome that includes geoflory (flowers located close to the ground), dull perianth coloration and yeasty fragrance (Wiens et al. 1983). A few other candidates in *Erica* and *Leucadendron* may also be therophilous. First reported in the 1970s (Rourke & Wiens 1977, Wiens & Rourke 1978, Wiens et al. 1983), therophily has also subsequently been found in the geophytes *Massonia* (Hyacinthaceae) and *Androcymbium* (Colchicaceae) and the parasitic *Cytinus* (Cytinaceae) (Johnson et al. 2001). These plants are not restricted to fynbos, but occur in karoo as well. The arguments for the distribution of therophily within fynbos are similar to those for bird pollination, but the more concentrated nectar lacks the water requirement, allowing therophily to occur in areas too arid for bird pollination. It occurs predominantly in proteoid and asteraceous fynbos. The rodents that visit the flowerheads, appear to rely on nectar only during their breeding season (Fleming & Nicholson 2002a, b). Interestingly, shrews are also pollinators, but appear to be visiting flowerheads for the insects, especially ants, found there (Fleming & Nicholson 2003). Flowering occurs in winter and spring (Rebelo 2001). Based on exclusion experiments, rodents account for about half the seed set in therophilous proteas (Fleming & Nicholson 2002a).

Exclusion experiments have shown that insects, particularly pollen-feeding bees and beetles, can make a substantial contribution to seed production in plants that otherwise appear adapted for bird or mammal pollination (Coetzee & Giliomee 1985, Wright et al. 1991a, Vos et al. 1994, but see Fleming & Nicholson 2002a, Hargreaves et al. 2004). Reciprocal experiments and the genetic fitness of seeds produced by the different pollinators have not been attempted so far.

Interestingly, fynbos is not known to differ markedly from other vegetation types in other pollination syndromes.

4.2 Climate and Growth-form Response

The mediterranean-type and all-year climate regimes have also influenced diversity in the region. The interplay between arid and wet climatic cycles as a species pump for alternatively contracting fynbos and succulent karoo vegetation has resulted in a proposal for a single 'Winter-rainfall Biome' encompassing both Fynbos and Succulent Karoo Biomes. However, only two biotic features stand out that link vegetation types between the two biomes, namely (1) the shared abundance of geophytes, and (2) the lack of trees.

Abundance of Geophytes: Fynbos, especially renosterveld, has a high diversity of bulbous plants—a striking feature shared with the Succulent Karoo (Esler et al. 1999, Procheş & Cowling 2004, Procheş et al. 2005, 2006). This suggests a climatic explanation, as fire and nutrients do not appear to be prime factors in the high diversity of geophytes in the region. The absence of annual grasses (and hence the threat of invasive annual grasses to geophytes) has been suggested as a reason. Geophytic diversity is four to five times the geophytic richness of the other mediterranean floras—geophytes comprise some 17% of the flora of the Cape Floristic Region (Goldblatt & Manning 2000a, Manning et al. 2002). Associated with the prevalence of bulbs is the occurrence of four species of exclusively fossorial rodents (mole rats), which subsist primarily on geophytes. More fynbos geophytic species have adopted an evergreen and woody habit than in renosterveld or karoo, and some fynbos Iridaceae have become uniquely shrub-like (*Aristea, Klattia, Nivenia, Witsenia*). The presence of geophytes in the dicots (e.g. *Oxalis* with 118 species) is very unusual, but again this is not confined to fynbos. Most winter-rainfall geophytes are dormant in summer and flower after leafing in winter, but the Amaryllidaceae—with large particularly poisonous bulbs—leaf in winter and flower

in autumn, usually after the first rains (Goldblatt & Manning 2000a). Most fynbos geophytes flower most prolifically after fire, and only rarely in older veld (Le Maitre & Midgley 1992) but in karoo geophytes, flowering is determined more by rainfall.

Interestingly, geophytes appear resilient to both frequent fire and heavy grazing regimes (McDowell 1988). However, it is thought that alien invasive grasses compete directly with the geophytic component (Vlok 1988). Certainly in eutrophic areas and old agricultural land, alien annual grasses are dominant at the expense of geophytes (Milton 2004). Heavy grazing might control the annual grasses, but fire and heavy grazing may favour alien annual grasses by virtue of their larger seed banks compared to those of indigenous grasses (Milton 2004). More research into the control of alien invasive grasses is required to ensure that the rich geophytic flora survives.

Lack of Trees: The absence of trees in fynbos (Moll et al. 1980) is a feature shared with renosterveld, and the Karoo, Desert and Grassland Biomes. As in arid vegetation types, trees are largely confined to riverine habitats. However, this is more a function of topography, with trees occurring in fire-safe habitats, as in grassland. Despite much debate, the reasons for the lack of trees in fynbos have never been resolved. Part of the reason for this is that alien trees (*Pinus, Acacia, Eucalyptus*) flourish in the Fynbos Biome. Arguably with adequate biocontrols these alien plants might not attain tree status in Fynbos (Le Maitre & Midgley 1992).

Climatic Reliability: Climatic variables such as the reliability (or predictability) of rainfall and mist precipitation may be linked to certain plant life-history traits in mediterranean-type ecosystems, as noted by Cowling et al. (2005). They suggest that germination response to soil moisture regimes, allocation of resources to below and above-ground biomass, and seedling mortality in relation to short-term stress are major candidates for further studies.

4.3 Fire as a Non-selective Grazer

Fynbos and renosterveld are fire-maintained systems (Figure 4.16). Of all fynbos and renosterveld vegetation units, perhaps only FFd 1 Namaqualand Sand Fynbos and FFq 1 Stinkfonteinberge Quartzite Fynbos are not exclusively driven by fire. Fire in fynbos burns on a 5–50-year rotation, usually in the order of 15–25 years. Fire regimes in renosterveld are largely unknown, but are assumed to be in the 2–10-year range. The fires naturally occur in late summer and early autumn, towards the end of the dry season, and their natural causes include rockfalls and lightning. With increasing population density in and around fynbos, man-made fires have become more frequent. The increased incidence of man-made fires has probably decreased the average fire size, without changing the fire-return interval at any location (Figure 4.17). Arguably, nutrients and climate are the primary determinants of the fire regime (Van Wilgen et al. 1992a, b, Bond & Van Wilgen 1996). Rather than concentrate on all the ramifications of fire, we will confine ourselves to several community-ecology issues such as the fynbos vegetation boundaries, boundaries of internal units, and alternative states maintained by fire.

4.3.1 Fire and Community Composition

Fynbos

Typically, boundaries within fynbos units are not determined by fire. However, fire does play a major role in determining species composition and community type. These effects are usually mediated by the fire temperature, which is controlled by air temperature, season, time of day, aspect, wind conditions, aeration, humidity, wood moisture content, veld age, and size of fuel storage (Van Wilgen et al. 1992a).

Although much is made about fynbos burning when too young, fynbos cannot burn until there is sufficient fuel to sustain a fire. Very frequent fires eliminate firstly the serotinous species, which being the dominant overstorey group and with its shading effect in veld older than 15–20 years, are the key species in community composition. However, young veld tends not to burn cleanly, and a mosaic of unburned patches is typical of areas where farmers attempt to burn as often as possible. These offer refugia to serotinous species. Species with soil seed banks appear to carry a proportion of the seed bank over to the next fire (Van Wilgen et al. 1992a).

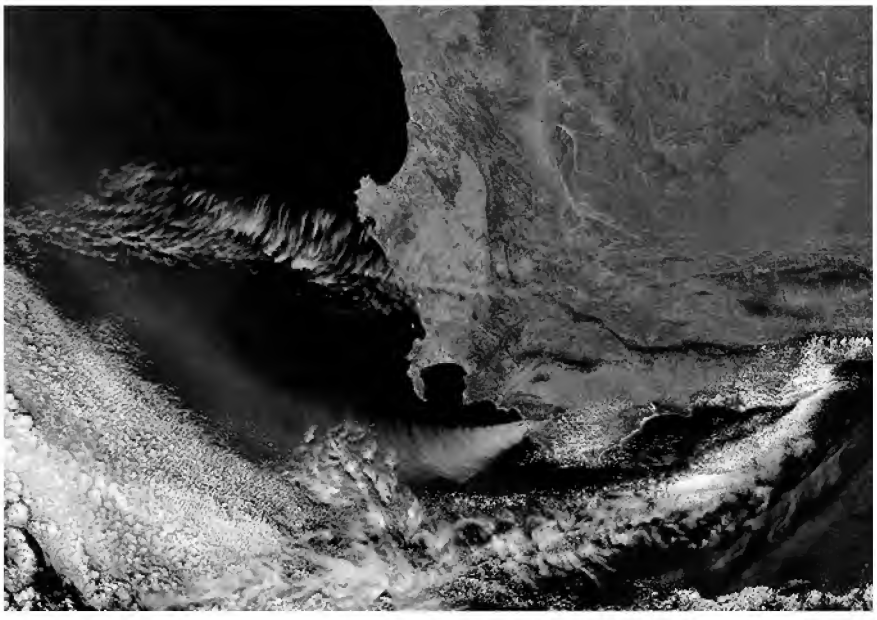

Figure 4.16 Satellite image of the devastating fires in the Overberg region near Cape Agulhas (February 2006) showing a huge smoke plume being carried deep into the southern Atlantic Ocean against a background of a massive western cloud- and precipitation-bearing front approaching the southwestern Cape. (Courtesy of NASA and the University of Maryland.)

Regular frequent fires, as for instance in fire belts, result in bole resprouting species becoming dominant, but the total cover of the area is unaffected. The relative abundance of obligate reseeder species versus resprouters is a good indication of historical fire frequency within any vegetation community. In proteoid fynbos this is complicated by aseasonal (spring) burns that reduce serotinous population sizes, allowing nonserotinous species to increase in cover. Thus very frequent fires or aseasonal burns can convert proteoid fynbos to its understorey equivalent of ericaceous, restioid or asteraceous fynbos, but extinction of the proteoid element is rare (Le Maitre & Midgley 1992, Van Wilgen et al. 1992a).

Aseasonal fires (spring versus the natural late summer or autumn fires) reduce population sizes of serotinous species by exposing seeds to rodent and bird predation for prolonged periods prior to germination in autumn. This reduces the cover of these key species in mature

fynbos, allowing resprouters to gain competitive dominance. Resprouter dominance is exerted by usurping space for post-fire seedling regeneration of obligate reseeders. Most aseasonal fires are managed block burns and firebelts (Van Wilgen et al. 1992a).

Hottest fires occur in more mature veld, where there is more fuel, and during the summer fire season. Very hot fires have two major effects on species composition. They incur a higher mortality of resprouting species, and in *Protea nitida* can reduce the plants from epicormic to bole resprouters. Hot fires also eliminate shallow seed banks. Most affected appear to be Asteraceae, with species of *Helichrysum, Stoebe* and *Syncarpha* the most marked of these. Presumably ericoid seeds occur in wetter soils and are less affected. Myrmecochorous and serotinous species appear to benefit most from very hot fires. The former are buried too deep to be killed by fire, and the latter are safe in their fireproof cones. Neither establish well in cool fires that leave a thick litter layer; presumably the germination cues are not triggered in myrmecochorous species, and seedling mortality is high in serotinous species. In myrmecochorous species the dormant seedbanks appear to persist to the next fire. It is not known how long-lived the seed banks are—possibly in the order of 40–80 years. Consequently, the species present in a stand of fynbos may depend as much on fire history as on habitat and species pool. Most management fires are cool, as manageability is a function of fire temperature, but natural fires burn larger areas and account for most of the area burned in any year (Bond 1985, 1997, Bond et al. 1990, Van Wilgen et al. 1992a).

Topography and rockiness drastically affect fire temperature, and favour smaller-seeded species. In addition, these species tend to have soft persistent leaves that retard fire, create much smoke and result in incomplete combustion at ground level due to oxygen starvation (aeration). Occurring in similar habitats, are myrmecochorous species, such as the Rutaceae, which appear to encourage fire with volatile oils. Presumably these two strategies are dominant after a particular fire and attempt to influence future fire temperatures to favour their regeneration niche (Van Wilgen et al. 1992a).

Rocky habitats also cool fires down sufficiently to allow canopy survival. This is a relatively rare strategy—*Leucospermum conocarpodendron* subsp. *viridum* and *Mimetes fimbriifolius* are the best known examples of this strategy. On sandstone both species are dominant in rocky areas and seldom reach tree status in open vegetation. In rugged areas where cooler fires do not penetrate, fire escapers such as *Protea glabra, P. rupicola, Widdringtonia cederbergensis* and *W. swartzii* survive (Van Wilgen et al. 1992a).

Fire also affects the minimum patch size of fynbos within non-fire vegetation types. Thus below 600 ha fynbos loses species, and below 4–15 ha fynbos cannot exist (Bond et al. 1988, Rebelo 1992b). This affects patches on hills and peaks within forest, thicket and karoo shrublands. The size of patches determines the probability of a lightning strike and therefore the fire interval. Where this exceeds 30–50 years, fynbos cannot exist (Bond et al. 1988). In larger blocks of fynbos, ignition is not as important as most fires enter any patch from ignition events outside the patch.

Renosterveld

Although renosterveld is clearly a fire-maintained system, there is little evidence as to what might constitute an ideal fire frequency (Von Hase et al. 2003). Estimates of 3–10 (up to 40) years exist (Rebelo 1992a). Presumably heavily grazed areas seldom burn. By contrast, ungrazed areas can accumulate sufficient fuel to maintain fire. Fire-safe habitats—including heuweltjies in some landscapes—contain thicket elements such as *Rhus* bush clumps. Similarly, fire-protected areas become dominated with *Rhus* bush clumps as on Signal Hill. Most grasses, annuals and bulbs survive under a high fire cycle, but many shrubs (and animals, such as the Geometric Tortoise (*Psammobates geometicus*) require 3–5 years to mature. Season of burn has a profound impact on vegetation composition in fynbos, and presumably also in renosterveld (Cowling et al. 1986). Thus early spring fires would prevent annuals, geophytes and most grasses from setting seed. Summer and autumn fires would not have these negative effects, but may—by virtue of their being hotter—change community composition to those plants with deeper soil seed and bulb banks. Similarly, patterns of grazing after fire would affect species composition, particularly the interplay between grasses and geophytic and shrubby components.

Some fire-associated strategies common in fynbos are absent from (e.g. serotiny) or rare (e.g. obligate reseeding, myrmecochory) in renosterveld. Fruit dispersal by birds is common in species of thicket clumps (Le Maitre & Midgley 1992).

A major complication in the study of renosterveld is the current insularisation of renosterveld. In areas where farmers do not regularly burn for grazing, the vegetation rapidly (within decades) converts to a thicket or a thicket mosaic. Britton & Jackelman (1996) argue that even in 25 year-old renosterveld (protected from grazing, and dominated by *Rhus* and *Hyparrhenia hirta*), the geophytes and perennials are actively growing and flowering and that renosterveld species can therefore survive in a fire-free Cape thicket. However, no controls were done and thickets tend not to contain as many geophytes as renosterveld (A.G. Rebelo, personal observations).

F.G.T. Radloff

Figure 4.17 Controlled fire in renosterveld shrublands on shale in the Potberg section of the De Hoop Nature Reserve (Overberg region).

4.3.2 Post-fire Regeneration

Seral succession has been poorly studied in the Fynbos Biome. The constraint of veld age on floristic and structural studies has resulted in a dearth of knowledge of pattern and process in early seral (i.e. immature) fynbos communities. The basic post-fire regeneration pattern is obvious and has general features: immediately after a fire, the 'fire lilies' (such as *Cyrtanthus, Watsonia*, etc.) are the first to emerge, sometimes within a few days of the fire (Figure 4.18). A few geophytic orchids and daisies flower only during these earliest periods, before seeds germinate (Le Maitre & Midgley 1992). If rain is delayed or late in autumn, then seed germination is delayed but most resprouters will commence regrowth. Similarly, early rains result in massive resprouting, but seed germination is usually tied to a strong cold requirement, ensuring that seeds germinate sufficiently well into winter to guarantee follow-up rains. Almost all recruitment appears to occur in the first and possibly second autumn following a fire. Conditions might be laxer in the all-year rainfall area, where it is not known whether spring recruitment might occur. During this period, all species present in later seral stages are present as seedlings, and no further significant recruitment occurs, with the exception of the aerial parasites *Viscum* and *Cassytha* (spread by birds from fire refugia). This lack of recruitment is thought to be a combination of rodent predation of seeds and overwhelming competition from established plants for water so that any seedling dies during the summer drought period. Most fynbos plants have seeds with strong dormancy- and post-fire-related cues for germination (Le Maitre & Midgley 1992).

In spring, large-scale flowering of geophytes and, where present, of annuals occurs. Some species flower only in the first spring, but many flower best two years after a fire. Few species produce more than a small fraction of flowers after the third year (Le Maitre & Midgley 1992).

The first year or two is dominated by resprouting species and fire ephemerals, with seedlings being small and relatively inconspicuous, although non-resprouting Restionaceae and Cyperaceae rapidly become dominant in some communities. The fire ephemerals are mainly Fabaceae, with *Aspalathus* being the most obvious element, Asteraceae (*Othonna quinquedentata* and *Ursinia crithmoides* require special mention), and some other families such as Campanulaceae (endemic genus *Roella*) and the monotypic endemic family Lanariaceae (*Lanaria lanata*). Fire ephemerals can reach 100% cover in shale and granite fynbos as a 0.5–1.5 m layer, but such dominance is rare in other fynbos types. These species peak 3–5 years after a fire, after which senescence eliminates them from the community, where they survive as seeds until the next fire. The effect of these species on seedlings of later seral stages is unknown, but later seral stages do not appear to be compromised by them. Slightly more long-lived, but in the same category, are many grasses and Asteraceae colloquially known as 'everlastings' or 'sewejaartjies' (e.g. of the genera *Anaxeton, Edmondia, Helichrysum, Phaenocoma*), of which many are harvested from young recovering veld for the cut flower trade (Le Maitre & Midgley 1992).

Resprouters remain alive in mature veld, but the flowering of most peaks in year 2 or 3 after which growth and flowering declines. Some species remain vigorous, but many seem to enter stasis with minimal new leaf production and few flowers. These species appear to recruit best when veld is burned when young (about 4–6 years old), with little recruitment following fires in older veld. Most mortality in resprouters occurs after regeneration, but it is characteristically low (< 5%), suggesting that resprouting plants may be hundreds of years old (Le Maitre & Midgley 1992).

Most species maturing after four years remain in the community, but the ericoids start emerging and becoming dominant after 4–5 years and the proteoids start emerging after year 4–7 and reach maximum canopy cover between year 8 (dense stands and wetter habitats) and year 15 (sparser stands and more arid situations). Although no mortality of proteoids is usually apparent until senescence sets in, shading and competition in the understorey do occur, but mortality rates are unknown. Usually after 30–40 years, senescence sets in. With most plants this manifests as shortening lengths of leaves on the branch tips, until the branches die. Serotinous species lose their seed banks, resulting in reduced populations after fire. Some inter-fire recruitment sets in as plants die off, but survival is still relatively low compared to after a fire. Most flowering ceases and skeletons (thanatocoenoses) form prominent features in the fynbos vegetation (Le Maitre & Midgley 1992).

Seral succession therefore mirrors structural complexity, with graminoid fynbos being replaced by restioid fynbos, asteraceous or ericaceous fynbos following, and proteoid fynbos dominant until senescence sets in and closed-scrub fynbos starts appearing. Although the species present and the number of plants remain constant, apart from the ephemeral component, dominance in height and cover alters dramatically as the community ages. Too frequent fires reset the seral complexity at lower stages. However, later stages are important, with proteoids a key element in shading and suppressing resprouters and thus maintaining local species diversity (Le Maitre & Midgley 1992).

Seral succession has not been recorded from renosterveld communities—pre-

E.G.H. Oliver

Figure 4.18 Explosive post-fire floral display of *Kniphofia tabularis* (Asphodelaceae) in the summit marshlands of the Hottentots Holland Mountains (Western Cape).

sumably the high fire frequency and grazing maintain renosterveld at an early seral stage.

4.3.3 Fire-adaptive Responses

There are at least three striking adaptation phenomena linked to the selective force of fire in the fynbos and renosterveld ecosystems. Of these, the high incidence of obligate reseeding species versus resprouters (Bond & Midgley 2003) and the occurrence of serotiny are most obvious (Bond 1984, 1985). Although these phenomena are related to fire, they are largely confined to fynbos on nutrient-poor soils. The absence of these strategies from other fire-prone ecosystems suggests that it is interplay between the low-nutrient soils and the predictable long-term (5–30-year) fire cycle that have allowed the evolution of these strategies rather than fire *per se*. A third adaptation is the incidence of smoke-induced seed germination.

Much has been made about the importance of smoke and smoke extracts in inducing germination in seed (De Lange & Boucher 1990, Dixon et al. 1995, Van Staden et al. 2000). Indeed for certain groups it is the only known way of breaking dormancy and obtaining seedlings in cultivation. Still we do not fully understand why natural smoke does not initiate germination in areas that do not burn, and why smoke may initiate germination of species typical of fire-free vegetation types such as karoo shrublands. While the physiological and horticultural importance of smoke is clear (Meets 2000, Brown et al. 2003, Boucher & Meets 2004, Brown & Botha 2004), the ecological significance of smoke requires further investigation, especially by setting *in situ* experiments.

4.4 Animal-plant Interactions

4.4.1 Large Mammal Herbivory

Herbivores change the structure, biomass, production and species composition of vegetation in heavily browsed or grazed areas of numerous and diverse ecosystems around the world. Both feeding strategies and physical disturbance by large vertebrates can alter important ecosystem properties, resulting in long-term changes in communities (Hobbs 1996, Owen-Smith & Danckwerts 1997, Frank et al. 1998, Olofsson et al. 2001, Augustine et al. 2003, Augustine & McNaughton 2004, Archibald et al. 2005). What role did (and do) large herbivores play in the vegetation dynamics of the Fynbos Biome?

Historical accounts indicate that a high and diverse number of large native herbivore species (> 20 kg) occurred in the Fynbos Biome and more specifically in the low-lying areas of the Western Cape at the time of European colonisation (1652) (Du Plessis 1969, Skead 1980, Rookmaaker 1989, Boshoff & Kerley 2001). There is little doubt that lowlands supported African elephant (*Loxodonta africana*), black rhino (*Diceros bicornis bicornis*), hippo (*Hippopotamus amphibius*), eland (*Taurotragus oryx*), mountain zebra (*Equus zebra zebra*), quagga (*Equus burchellii quagga*), ostrich (*Struthio camelus*), red hartebeest (*Alcephalus buselaphus*) and grey rhebuck (*Palea capreolus*). In addition, the lowlands to the east of the Overberg also hosted populations of Cape buffalo (*Syncerus caffer*), blue antelope (*Hippotragus leucophaeus*; extinct around 1800) and bontebok (*Damaliscus pygargus pygargus*: Figure 4.19), with bushbuck (*Tragelapus scriptus*) present in forest and thicket patches. It is not exactly clear how far west quagga (a subspecies of Burchell's zebra; extinct in 1876) ventured and what its ecological relationship with mountain zebra was. On the West Coast, gemsbok (*Oryx gazella*) has been reported as far south as Saldanha but is believed to have been only an occasional visitor to this area and more abundant from Namaqualand northwards. Springbok (*Antidorcas marsupialis*) occurred inland in both the Warme and Koue Bokkeveld regions, but was most likely restricted to these parts within the Fynbos Biome.

In association with these large herbivores all the members of the large carnivore guild of southern Africa were found, including Cape lion (*Panthera leo*), leopard (*Panthera pardus*), wild dog (*Lycaon pictus*), cheetah (*Acinonyx jubatus*), spotted hyaena (*Crocuta crocuta*) and brown hyaena (*Hyaena brunnea*), with attendant vultures and birds of prey. Unfortunately the size of the populations of these animals changed very rapidly after colonial settlement. It is estimated that by the year 1700 there was no game within 200 km of Cape Town and that by 1800 most large mammals (above 50 kg) and birds had been driven close to extinction within the area today known as the CFR (Rebelo 1992a). Most of these extinctions were due to hunting for meat and sport, or the elimination of predators, scavengers and 'problem' animals (Rebelo 1992a, Krug et al. 2004b). Game animals were, however, not the only animals present at the time of colonisation. Around 2 000 years ago, the Khoekhoen introduced livestock (sheep and later also cattle) to the Fynbos Biome and the number of domestic livestock roaming the Cape forelands could have run well into the thousands with the arrival of the Dutch colonisers (Deacon 1992). Entries in Van Riebeeck's diary state that the Khoekhoen, eager to trade, gathered in such numbers with their livestock around the fort in Table Bay in December 1652 that they could easily have captured 12 000 cattle if they were so inclined (Thom 1952). A later entry (14 January 1653) gave an estimate of at least 20 000 cattle and sheep

L. Mucina

Figure 4.19 Bontebok (*Damaliscus pyrgargus pyrgargus*)—a conservation symbol of the Fynbos Biome.

present in that December. Whether these animals were permanently kept on the coastal lowlands and at such densities is, however, debatable as the same entry mentioned cattle trade by these Khoekhoen with tribes 'far inland', indicating migration by these people.

Little is known about the past distribution of large herbivores within the Fynbos Biome. It appears that the largely accepted opinion (Bigalke 1979, Cody et al. 1983, Morrow et al. 1983, Johnson 1992, Rebelo 1992b, Owen-Smith & Danckwerts 1997) is that the sandstone, sand and limestone fynbos did not support large resident herbivore populations and that they rather concentrated on renosterveld on the more nutrient-rich soils. However, this is based primarily on the exceptionally low nutritional status of fynbos (Joubert & Stindt 1979, Campbell 1986b, Le Roux 1988, Johnson 1992) rather than on historical records or habitat choice experiments. The reviews of historical accounts (Du Plessis 1969, Skead 1980, Rookmaker 1989) are vague with regard to the exact areas and habitats occupied (Boshoff & Kerley 2001). Even recent reviews (e.g. Hendey 1983a, b) stating that the influence of large mammals must have been 'significant and are under-appreciated' and that they might have been able to keep the vegetation more open and grassy than today, fail to distinguish between fynbos and renosterveld, referring to both as 'fynbos'. This is in contrast to opinions such as that of Rebelo (1992b) suggesting that the large herbivores never played a major role in the dynamics of nutrient-poor fynbos communities, but were largely confined to renosterveld.

The influence of large herbivores on the Fynbos Biome ecosystem has for the most part been a neglected topic. At the Third International Conference on Mediterranean-type Ecosystems held in 1980 it was concluded that there was very little understanding of the relationship between soil nutrient status, plant nutrition and the vertebrate faunas of any of the mediterranean-like ecosystems (Cody et al. 1983, Morrow et al. 1983). It appears that, for at least the Fynbos Biome, very little has changed since then.

Published studies on large native herbivores in the Fynbos Biome have been conducted mainly in the Bontebok National Park and Elandsberg Private Nature Reserve, with some isolated contributions from the Cape of Good Hope Nature Reserve (now part of the Table Mountain National Park) and De Hoop Nature Reserve. In the Bontebok National Park (primarily FFc 1 Swellendam Silcrete Fynbos, with patches of FRs 13 Eastern Rûens Shale Renosterveld) studies focused on some aspects of Grey Rhebuck ecology (Beukes 1984), Bontebok behaviour (David 1973, Van Zyl 1978) and Bontebok population dynamics (De Graaff et al. 1976). Both Novellie (1987) who focused on grassy elements, and Beukes (1987) who studied especially the shrubby component, conducted studies that looked into the interrelationships between fire, herbivory and vegetation cover. Both studies clearly showed the preference of Bontebok and Grey Rhebuck for recently burnt fynbos. Beukes (1987) reported on a dramatic drop in the utilisation of vegetation older than four years. Novellie (1987) found that intense grazing after fire is not necessarily deleterious to the preferred grass species. Luyt (2005) looked into habitat preference and stocking densities for Bontebok within the park found that Bontebok prefer recently burnt areas and may delay the re-establishment of shrubs if too small an area is burnt at a given time. A small burnt patch can attract a very high density of animals that suppress shrub seedling establishment by indiscriminate grazing of any new growth. Bontebok seek out *Cynodon dactylon* grazing lawns and might also create and maintain these lawns by positive feedback nutrient loops.

The Elandsberg Private Nature Reserve recently became the focus point of research regarding the restoration of West Coast renosterveld (Krug et al. 2004a, b), although most of the study area is FFa 3 Swartland Alluvium Fynbos. Midoko-Iponga (2004) found that both browsing and competition with grass played a role in transplanted shrub seedling (5 cm high) establishment on old lands, but that competition between shrubs and grasses was more important, although the role of large herbivores via grazing was not included. Shiponeni (2003) looked at seed dispersal by large herbivores (endozoochory) and found that it played an important role in the dispersal of seeds. *Cynodon dactylon* and several alien invasive grasses were the dominant species dispersed by this means. Here large herbivores may also be instrumental in the establishment and maintenance of *Cynodon dactylon* grazing lawns on old lands. Walton (2006) studied the influence of grazing on vegetation dynamics after ploughing and found that succession on old fields was retarded by grazing, and the establishment of palatable shrubs, such as *Anthospermum* and *Hermannia*, was particularly slow. These results must further be treated with caution with regard to historical/natural ecosystem processes—nearly two thirds of the large herbivores were historically not indigenous to the Elandsberg Reserve, the vegetation is not renosterveld and this study focuses on recovery in fallow lands.

In the Cape of Good Hope Nature Reserve, Langley & Giliomee (1974) found that the introduced population of Bontebok favoured recently burnt areas, fire breaks and well-established *Stenotaphrum secundatum* lawns. In De Hoop Nature Reserve, Cape Mountain Zebra demography (Lloyd & Rasa 1989) and the decline in Bontebok populations experienced between 1984 and 1990 (Scott 1993) have been studied. The main reason for the population decline was attributed to the lack of suitable habitat in the form of recently burnt veld. A rapid improvement in Bontebok body condition did occur after a controlled fire in 1991, but a subpopulation without access to newly burnt areas also showed an improvement in body condition and survival. Here Bontebok also concentrate on *Cynodon dactylon* lawns and recently burnt veld. The last study of relevance is that of Milewski (2002) reporting on the diet of forest elephants roaming the forest/fynbos ecotone near Knysna. Based on opportunistic qualitative data obtained from forest guards, he provides evidence that elephants utilised nutrient-poor fynbos (FFh 9 Garden Route Shale Fynbos). However, in contrast to these, large game numbers at both the Cape of Good Hope Nature Reserve (mainly sandstone fynbos) and in the original Bontebok National Park (limestone fynbos) declined and animal health declined largely due to bone diseases and gut parasites. This resulted in the removal of game from the Cape of Good Hope Nature Reserve and the relocation of the Bontebok National Park from the Bredasdorp area to south of Swellendam.

Grazing lawns have been noted in both recent and old studies (Langley & Giliomee 1974, Scott 1993, Shiponeni 2003, Luyt 2005, Walton 2006) as being an important habitat for large herbivores and especially Bontebok. If large herbivores are capable of establishing and maintaining these grazing lawns, it might provide some new insight on how large herbivores managed to survive on the coastal lowlands. However, apart from Hippo, no short-grass grazer occurred naturally on the West Coast lowlands. Natural grazing lawns may thus have been confined to the regions east of the Overberg Mountains.

McDowell (1988) compared the influence on total cover and species diversity of heavy browsing by sheep with adjacent areas ungrazed by domestic livestock for 14 years at Eensaamheid (primarily FFa 3 Swartland Alluvium Fynbos, with some FRs 9 Swartland Shale Renosterveld also present). There

was no significant decline in total cover or species diversity, but a definite change in the species composition of the flora was noted. Species of the Poaceae and Rutaceae declined while Asteraceae and Iridaceae increased. Three Proteaceae species were absent from grazed areas and three Thymelaeaceae species were dependent on grazing for survival. Grazing by stock can thus have either a negative or positive influence, depending on how it is managed. In the Riviersonderend Mountains catchment area, frequent burning and intensive grazing (coupled with trampling) caused a reduction in floral diversity and led to erosion (Le Roux 1988). The latter author recommended that all domestic grazing in mountain fynbos must be stopped as it was not only detrimental to the vegetation, but also economically unviable due to the low nutritional status of the veld.

Some studies suggest that perhaps renosterveld contained more grass (primarily *Themeda*) than is currently the case (Sparrman 1786, Levyns 1956, Joubert & Stindt 1979, Skead 1980, Cowling 1984, Scholtz 1986, Stock et al. 1992a, Rebelo 1995, Krug et al. 2004b, Newton & Knight 2004). About 50 years after European colonisation it was first noted that the amount of grass available for grazing and thatching was declining markedly. At about this time, early naturalists started noting an increase in the abundance of *Elytropappus* throughout the region, apparently due to the increase in grazing pressure. By 1800 this process appeared to have occurred throughout the renosterveld (Cowling et al. 1986).

Isotope analyses yielded no evidence that Swartland Shale Renosterveld could have once been covered by C_4 grass species such as *Themeda triandra* (Stock et al. 1992a). The possibility does, however, exist that the grassland consisted of C_3 grasses but this does not show via isotope analysis.

Severe and continuous overgrazing of freshly burnt veld by domestic stock has been proposed as the cause for the presumed change from a grassland to a shrubland (Sparrman 1786, Du Toit & Du Toit 1938, Joubert & Stindt 1979, McDowell 1988). This followed the advent of settled agriculture, which changed the disturbance regime from an intense and localised, pulsed grazing system by indigenous and domestic livestock coupled with a variable fire frequency, to a system of continuous overgrazing and a fixed burning cycle (Cowling et al. 1986). However, the absence of large native mammals over the past 300 years, more specifically the lack of large browsers that consume the dominant shrubs, has been suggested as a reason for the current existence of renosterveld as a shrubland (Rebelo 1995, Krug et al. 2004b). Until more research is undertaken on the impact of large mammals on renosterveld shrubs, these hypotheses remain speculative.

The interplay between shrubs and grasses in renosterveld is not well understood, and probably was greatly influenced by grazing pressure and fire intervals. Presumably some areas such as natural grazing lawns dominated (as today) by *Cynodon dactylon* and other grasses, were well utilised, whereas others were dominated by shrubs and were relatively less grazed. Thicket probably occurred in fire-safe environments, including heuweltjies and rocky areas. Presumably river margins supported *Acacia karroo*-dominated thickets on the South Coast, although transformation on the West Coast pre-dates any records of the riverine vegetation. Alien grasses are an additional concern: heavy grazing might control the annual grasses, but fire and heavy grazing may favour alien annual grasses by virtue of their larger seed banks compared to those of indigenous grasses (Milton 2004). It is ironical that 300 years after renosterveld was reputedly converted from a tussock grassland to a shrubland by overgrazing, today it is threatened by a conversion to grasslands dominated by short-lived alien flora.

In summary, we know very little about the influence of large mammals on the vegetation of the Fynbos Biome. We know with reasonable confidence which species occurred here in the resent past (last 2 000 years), but are unsure of their exact whereabouts, numbers and impact. We speculate that they focused on the more fertile renosterveld areas, avoiding the nutrient-poor fynbos and strandveld. There is reason to believe that these preferred renosterveld areas might have been grassier in the past, but this is not verifiable. The interplay between shrubs and grasses in renosterveld is still not well understood, and probably was greatly influenced by grazing pressure and fire intervals. Fluctuation between the shrubland and grassland states is presumed to have occurred, but for the moment the exact mechanisms are unclear.

4.4.2 Other Animal-plant Interactions

The Fynbos Biome shows an exceptional diversity of pollination systems (Rebelo 1987b, Johnson 1992, 1996b). Their most outstanding feature is a high degree of specialisation (Johnson & Steiner 2000). A recent synthesis of data on pollination systems in southern Africa, much of it from the Fynbos Biome, revealed that pollination systems in southern Africa tend to be more specialised than those in the temperate regions of the northern hemisphere (Johnson & Steiner 2003). Indeed, pollination by a single animal group, even species, is the norm rather than the exception in many plant families in the Fynbos Biome (Johnson & Steiner 2003). This applies even to abiotic pollination where *Cliffortia* (Rosaceae, 114 species) and most Restionaceae (318 species) are all wind-pollinated.

Plant specialisation for particular pollinators often leads to the evolution of distinctive suites of floral traits known as 'pollination syndromes' (e.g. Faegri & Van der Pijl 1979). The seminal paper on pollination syndromes by Vogel (1954) was, in fact, inspired by his experience with the southern African flora, particularly its representatives in the Cape region. It has been argued that evolutionary specialisation for pollination by different animals has been a key driving force behind the rampant speciation in the Cape region (Johnson 1996b, 2006). This is based largely on the observation that sister taxa often differ in their pollination systems (Johnson & Steiner 1997) and that large genera show great diversity in pollination systems (Johnson 1996b, Johnson et al. 1998, Goldblatt et al. 2000, 2001). On the other hand, many large genera have only a single pollination syndrome, including wind pollination. The existence of specialised pollination systems also has implications for conservation because these plants may be particularly vulnerable to changes in land use that affect the pollinator fauna (Bond 1994, Johnson & Steiner 2000, Donaldson et al. 2002). Here we outline some of the major pollination syndromes in the Fynbos Biome:

Long-proboscid Fly Pollination: Highly specialised pollination systems involving long-proboscid flies belonging to the families Nemestrinidae, Tabanidae, and Bombyliidae are well developed in the CFR (Goldblatt & Manning 2000b). These systems are shared between fynbos, renosterveld and succulent karoo shrublands. The flies are flower specialists that feed mostly on nectar (although female tabanids take blood meals and Bombyliidae feed extensively on pollen). Some nemestrinid and tabanid flies have proboscides longer than 50 mm (Johnson & Steiner 1997, Manning & Goldblatt 1997a). This syndrome is concentrated in the Iridaceae, Orchidaceae, Geraniaceae and Ericaceae and probably involves over 100 species (McDonald & Van der Walt 1992, Manning & Goldblatt 1996, Struck 1997, Goldblatt & Manning 2000b). Flies with shorter proboscides are probably also important as pollinators of small open flowers,

but there are fewer documented cases of specific associations between plants and these flies.

Beetle Pollination: A distinctive feature of the winter-rainfall region of South Africa is the syndrome of bright (red, orange or yellow) odourless and bowl- or disc-shaped flowers pollinated by monkey beetles (Scarabaeidae: Rutelinae: Hopliini) (Picker & Midgley 1996, Goldblatt et al. 1998). Scarab beetles often use flowers as mating rendezvous sites, but there is no strong support for the hypothesis (Steiner 1998) that dark patterns in the centre of these flowers attract male beetles (Johnson & Midgley 2001). On the other hand, the attraction of the beetles to the bright long-wavelength colours is now well documented (Picker & Midgley 1996, Johnson & Midgley 2001). Pollination by small beetles (Nitulidae, Alticidae, Curculionidae) has been suggested for many fynbos taxa including *Leucadendron* (Proteaceae) and *Audouinia* (Bruniaceae) (Hattingh & Giliomee 1989, Wright et al. 1991b, Hemborg & Bond 2005). Beetle pollination is widespread across all vegetation types and there is no documented guilds specific to any major vegetation type.

Butterfly Pollination: The relationship between a guild of about 20 mainly fynbos plants (in the Iridaceae and Orchidaceae) and the satyriine butterfly *Aeropetes tulbaghia* is one of the classic examples of floral specialisation in plants. In this system, the butterfly is attracted to large red flowers, leading to convergent evolution in these traits among plants in the guild (Johnson 1994a, Johnson & Bond 1994, Goldblatt & Manning 2002a). The guild includes several very rare species that depend completely on the butterfly for their survival (Bond 1994), and is most prominent in fynbos on southern slopes of the mountains, flowering peaking in late summer. Many other butterflies are also pollinators but few studies have been undertaken on them.

Moth Pollination: Data presented by Johnson (2004) indicate that less than 3% of flowering plants in the CFR are moth-pollinated, as opposed to 6–7% in the eastern summer-rainfall region. The difference is even more striking for hawkmoth-pollinated plants, which are virtually absent from the CFR (Manning & Snijman 2002). The most likely reason is a paucity of plants in families such as Balsaminaceae and Solanaceae that are the typical larval food-plants for hawkmoths (Johnson 1997b). Pollination by small settling moths (Noctuidae and Geometridae) has been recorded for several taxa (Johnson et al. 1993, Johnson 1997a), but the relative contribution of moth pollination within units of the Fynbos Biome is unknown.

Bee Pollination: Bee diversity in southern Africa increases from east to west, with a maximum diversity in Namaqualand (Eardley 1989). There is no doubt that these insects as a group are the most important pollinators in the CFR. The Cape Honeybee, *Apis mellifera capensis*, is confined to this region and is specifically adapted for colony survival during the cold and wet Cape winters (Hepburn & Crewe 1990, 1991, Hepburn & Guillarmod 1991). Carpenter bees also play a major role in the pollination of larger flowers, especially legumes (Watmough 1974, Johnson 1993). They are abundant in the fynbos, especially after fires when charred woody stems are used as nesting sites (Watmough 1974, Johnson 1997b), and also in forests where woody nesting sites are more abundant. Smaller solitary bees have also been implicated in the pollination of several CFR plant species (Johnson 1994b, Johnson & Steiner 1994). Oil-collecting bees in the genus *Rediviva* (Melittidae) pollinate Scrophulariaceae, Orchidaceae and Iridaceae with oil-producing flowers (Steiner 1989, 1993, Manning & Goldblatt 2002, Steiner & Whitehead 2002). On account of their unusual floral reward and the low diversity of *Rediviva* bees, oil-producing plants have extremely specialised pollination systems (Johnson & Steiner 2003). There appears to be no pattern of bee syndrome pollination within vegetation types of the Fynbos Biome, indeed most are shared with succulent karoo shrublands to the north.

Bird Pollination: The significance of bird pollination in fynbos as compared to renosterveld, strandveld and karoo is discussed under the effects of nutrient-poor soils (see Section 4.1). Although the fynbos bird-pollination guild comprises only four pollinators (two endemics), they service almost 400 species of plants. By contrast, strandveld and renosterveld have only two pollinators and a few dozen plant species, comparable with bird pollination systems in the other biomes, although they tend to have more bird species. An unusual strategy is found in *Microloma* (Apocynaceae) by which pollen packets are placed on the tongue of birds (Pauw 1998).

Nonflying Mammal Pollination: Among shrubs in the Fynbos Biome, this syndrome is confined primarily to proteoid and asteraceous fynbos. The syndrome is also known in geophytes (*Massonia depressa*; Johnson et al. 2001) and probably in *Androcymbium* (Colchicaceae) and *Cytinus* (Cytinaceae). A proper appraisal of the geophytic component is required.

Bird Fruit Dispersal: Ornithochory is virtually absent from fynbos, but is well represented both by bird and plant species in strandveld and renosterveld. Its absence in fynbos is attributed to the lack of a regeneration niche, where the fruit and seedlings are killed by fire. By contrast, in other systems, birds target favourable microhabitats most suitable for germination and establishment (Le Maitre & Midgley 1992).

5. Origins of the Cape Flora

5.1 Palaeoecological Framework

Rare evidence of the origins of species of the CFR is available in the form of fossil pollen of Tertiary age while fossil charcoal only provides information about its most recent history during the Late Quaternary. In comparison with pollen and spore records from the rest of the southern hemisphere, the early to middle Cretaceous in South Africa has not yet developed clearly unique features (Scott 1976, McLachlan & Pieterse 1978). Pollen from Banke in Namaqualand, however, suggests that some groups that could have developed into certain fynbos elements like Thymelaeaceae, Restionaceae and Ericaceae, were already developed by the Latest Cretaceous or Palaeogene, although the vegetation in which they occurred was of a subtropical type (Scholtz 1985). According to Linder (2003) who thoroughly reviewed the molecular, geological, climatological, palaeontological and other evidence for diversification of the plants of the CFR, it may have been in existence in isolated locations in the nutrient-poor mountains of the Cape early during the Tertiary period but its dramatic spread in the region may have taken place only by ca. 8–10 mya. Available fossil evidence is not dated well enough to narrow this interval further but the following broad picture of its origin and history can be derived from it.

In Knysna, southern Cape region, subtropical vegetation with Restionaceae, palms and forest elements was reported from lignite deposits (Thiergart et al. 1962, Helgren & Butzer 1977, Coetzee et al. 1983). Tertiary pollen assemblages in the southwestern Cape at Noordhoek and Langebaanweg, suggest a markedly different subtropical woodland vegetation that include palms (Coetzee 1978a, b, Coetzee & Rogers 1982, Coetzee et al. 1983, Coetzee & Muller 1984). Although precise dates have not been established for the Knysna or southwestern Cape assemblages, they are apparently of Neogene age. Controversial opinions about the age of the Knysna deposits have been expressed but on the basis of tectonic evidence they

are thought to be of Miocene age (Thiergart et al. 1962, Maud & Partridge 1987, Partridge & Maud 1987). The tropical elements in both regions are probably from a period before the development of the current circum-Antarctic ocean system, the Benguela Current and the enlarged Antarctic Ice Sheet (Shackleton & Kennet 1975, Van Zinderen Bakker 1975, Vail & Hardenbol 1979). These events possibly accompanied a transition from subtropical forest pollen in the Late Miocene to typical fynbos and strandveld elements in the Early Pliocene associated with the well-known fauna from the Varswater Formation at Langebaanweg (Coetzee & Rogers 1982, Hendey 1984, Scott 1995). Asteraceae pollen evolution accompanying the change to Fynbos Biome types showed earlier low-spine *Gerbera*-like pollen (Mutisiae) and later more diverse and typical modern long-spine and other forms, a situation which seems to be paralleled in South America (Coetzee 1978a, Barreda 1993).

Reconstruction of the Quaternary vegetation of the Fynbos Biome on the basis of fossil pollen data suggests that marked changes took place during this period. More extensive woodland at different times before the Late Glacial Maximum (LGM) is suggested by pollen in lagoon deposits (Schalke 1973) and charcoal from Elands Bay Cave of > 24 000 years cal. BP (Parkington & Cartwright 1997, Cowling et al. 1999a, Parkington et al. 2000). Pollen in hyrax dung suggests that the LGM in the northeastern part of the Cederberg range (Pakhuis Pass) bordering on the Karoo, was characterised by asteraceous shrubland (renosterveld) with fynbos elements such as Proteaceae, Ericaceae, *Passerina* and *Lobostemon* etc. (Scott 1994, L. Scott & S. Woodborne, unpublished data). The LGM was by no means a uniform event and showed regular fluctuations in temperature, moisture availability and seasonality (L. Scott & S. Woodborne, unpublished data). In view of climatic forcing of the earth's orbital variations, the latter authors pose the question: What if the fynbos of the LGM experienced a slight shift to more summer rain during the LGM? If so, cool growing seasons prevented it from changing to a more typical summer-rain vegetation type. Variations in ^{18}O values from the Cango Caves ca. 300 km to the east, suggest a temperature difference of ca. 5°C between the LGM and Holocene (Talma & Vogel 1992). It has been suggested that fynbos and renosterveld elements migrated far to the north to northern Namibia during the LGM following northward penetration of winter rain, according to Shi et al. (2000) who found high concentrations of Ericaceae and Restionaceae in marine sediments off the mouth of the Cunene River. On the basis of fossil pollen of LGM age from the Brandberg/Daures (Namibia) and elsewhere in South Africa and an investigation of source areas and long-distance transport, Scott et al. (2004) consider this unlikely and give different explanations for the composition of the pollen assemblages. Temperatures at the end of the LGM started increasing sharply ca. 16 000 years cal. BP as recorded by pollen changes from the Pakhuis Pass and the vegetation accordingly changed to woodland, with *Dodonaea, Olea, Rhus*, Ebenaceae and Proteaceae, etc. (L. Scott & S. Woodborne, unpublished data). Paralleling the transition at Pakhuis Pass, charcoal and pollen from archaeological sediments in Boomplaas Cave (Deacon et al. 1984, Scholtz 1986) adjacent to the Cango Caves, show open renosterveld vegetation (*Elytropappus* and *Euryops*) changing to more woodland. The hyrax dung sequence from the Pakhuis Pass which, however, has a much higher sample resolution than the Boomplaas record, suggests that regular variations persisted throughout the Holocene, indicating markedly contrasting wet and dry phases on a millennial scale, with variations in pollen of Restionaceae, Cyperaceae, Asteraceae and succulent Aizoaceae types (L. Scott & S. Woodborne, unpublished data). The Pakhuis Pass results are, however, in contrast with previous pollen data from the higher mountain peaks of the Cederberg, which suggested that very constant climatic conditions prevailed during the LGM transition and persisted throughout the Holocene, with only *Widdringtonia cederbergensis* showing a very gradual decline (Meadows & Sugden 1991, 1993). A low degree of change in the high mountain fynbos of the Cederberg during the terminal Pleistocene according to Cowling et al. (1999a) might be explained by different climatic regimes between the moist mountain peaks and the area to the east which lies in the rainshadow of the range.

Late Holocene vegetation was apparently more open in the fynbos environment and the change in firewood in Boomplaas Cave from species on adjacent mountain slopes to *Acacia karroo* ca. 2 000 years ago, might have been due to the necessity to collect firewood from valley bottoms (Deacon et al. 1984, Scholtz 1986, Scott & Lee-Thorp 2004). An increase in more C_4 grassland in the area during this time is indicated by the ^{13}C values from a stalagmite in the nearby Cango Caves (Talma & Vogel 1992). According to the pollen contents, present values of *Dodonaea* and *Euclea* pollen at the Pakhuis Pass are much reduced in comparison to the late Holocene. This could possibly be as a result of modern human influence on the vegetation (Scott 1994).

Palynological evidence from coastal lakes and swamps, e.g. Hangklip (Schalke 1973), Groenvlei (Martin 1968) and Verlorenvlei (Baxter & Meadows 1994) suggests that coastal vegetation composition did vary markedly during the Holocene. At Groenvlei the fynbos that occurred during the early Holocene was replaced by coastal forest (Martin 1968). At Verlorenvlei a middle Holocene salt-marsh environment associated with raised sea level changed to a freshwater one, while it has been inferred that anthropogenic disturbance since ca. 1 700 AD is responsible for the development of the current Verlorenvlei environment (Baxter & Meadows 1994).

5.2 *Phylogenetic Perspective*

The overall lack of fossil plant evidence (Deacon et al. 1983; see also Section 5.1 above) from the region of the current Fynbos Biome makes the inference of palaeo-vegetation patterns very difficult. It is therefore not surprising that alternative sources of information have been sought. Progress in the field of molecular biology driven especially by technological advancement of nucleic acid analysis and the methodological revival of cladistic inference offers unique and powerful tools of phylogenetic inference. Due to its legendary richness, the Cape is in the forefront of phylogenetic studies (Barraclough 2006, Linder 2006), and the Fynbos Biome is possibly one of the best researched biomes in the world in terms of using phylogenies in disentangling its origin and evolution.

It is amazing that much of the richness of the CFR (about 50%) is concentrated in only 33 major clades, which most probably originated and radiated within the CFR (Linder 2003, Linder & Hardy 2004), and are largely confined to fynbos. The taxonomic expression of this is an extraordinary abundance of large genera (containing more than 100 species), e.g. *Erica* with 658 species (Linder & Hardy 2004, Linder 2005b, E.G.H. Oliver personal communication). Another intriguing phenomenon emanating from the high species:genus ratio is the remarkable small-scale (habitat-level) co-occurrence of many congeners, defying entrenched ideas about the role of competition (hence niche differentiation) in community assembly. Procheş et al. (2006) found that in recently radiated classes typical of evolutionary young biomes (such as the Fynbos Biome), the co-occurring

species tend to be more closely related than predicted by classical niche theory.

At large temporal scales, the governing paradigm of the past was that the Cape flora is a *mixtum compositum* of three components, namely (1) a Gondwanan element (also called 'Antarctic' by some)—a relict of the Cretaceous Gondwanan flora, (2) an African element, accounting for the bulk of the Cape flora, and (3) an Eurasian element, supposed to have migrated recently along the eastern and southern African mountains to the CFR (see Adamson 1958, Linder et al. 1992, Linder 2005b citing Levyns 1962 as further sources of these ideas). Phylogenetic analyses, however, shed different light on these ideas by pointing towards the importance of post-Gondwanan intercontinental dispersal. In general, large-distance intercontinental dispersal events do not seem to be rare (Sanmartín & Ronquist 2004). The CFR appears to be a long-term assemblage with a strong Austral, rather than African, relationship (Linder 2005b). Furthermore, the dispersal from CFR to the high mountains of the afromontane archipelago has been suggested as the more probable direction, rather than the reverse (Galley & Linder 2006, Reeves et al. 2006; see also Chapter 8 on Grassland).

How old then is the Fynbos Biome? Very roughly we presume that the Mid-Miocene vegetation of the southwestern Cape was (sub)tropical (Axelrod & Raven 1978, Linder 2003, Linder & Hardy 2004) with ancestral lineages of the modern fynbos flora possibly restricted to the mountains. The climate of those times was also (sub)tropical, mesic and with no pronounced dry season. The steepening of the global pole-to-equator climatic gradient linked to complete glaciation of Antarctica and the associated strengthening of the upwelling of cold waters along the Atlantic seaboards of southern Africa which started some 8–10 mya (Siesser 1980), blocked off the summer rainfall, leaving only winter rainfall to dominate the southwestern Cape (Linder & Hardy 2004); the eastern regions of the current Fynbos Biome presumably still retained some share of the summer rainfall. The (sub)tropical flora and vegetation of the southwestern Cape was almost obliterated, perhaps except for the remnants of relict forest and fynbos thicket (see Section 1.4.4) patches, opening vacant habitats for fast-radiating lineages of the Cape clades, facilitated by regular fires in the hot and dry summers (Linder & Hardy 2004). According to Goldblatt (1997) the Cape flora is not older than Pliocene age (less than 5 mya), while Cowling & Pressey (2001) suggest that the major diversification is of Late Pliocene age. Richardson et al. (2001) found that the initiation of the *Phylica* radiation was in the Late Miocene, but other dated phylogenetic studies suggested older radiation dates: Mid-Miocene for *Pelargonium* (Bakker et al. 2005) and *Indigofera* (Schrire et al. 2003), Oligocene or Early Miocene for some tribes of the Iridaceae (Goldblatt et al. 2002), and Oligocene for African clades of Restionaceae (Linder & Hardy 2004). On the other hand, the radiation in *Heliophila* (Mummenhoff et al. 2005) was found to be of Pliocene age. It appears that adaptive nature of the radiations is a common phenomenon (Goldblatt et al. 2002: *Moraea*; Verboom et al. 2004: *Ehrharta*; Linder & Hardy 2005: *Thamnochortus*; Manning & Goldblatt 2005: *Tritoniopsis*).

Although the earliest recruitment of an angiosperm lineage into the Cape flora has been dated to the Cretaceous, more lineages have been incorporated into the flora, not really hindered by the opening of the southern oceans (Linder 2005b). The few dated molecular phylogenies available to us suggest a step-wise birth of the biome through accession of diversity (resulting from radiations) over the past 35 my, rather than a boom-like dramatic change of flora as a consequence of a unique change in environmental conditions in the palaeohistory of the Cape (Linder 2005b).

We hypothesise that also the major floristic component of the intrazonal fynbos thicket and strandveld vegetation is a relict of past subtropical periods (see also Linder 2005b). The dominance of genera of Anacardiaceae (*Rhus*), Celastraceae (*Cassine, Gymnosporia, Lauridia, Maytenus, Mystroxylon, Pterocelastrus, Robsonodendron*), Ebenaceae (*Euclea, Diospyros*) and Sapotaceae (*Sideroxylon*) with their evolutionary roots (and current centres of diversification) in the tropics, supports our claim. We further propose, alongside earlier suggestions (Levyns 1964), that the strandveld shrublands of the Cape might be in part relicts of old resident Mid-Miocene woodlands, which retreated to nutrient-rich and climatically more stable, mild (buffering function of the ocean) and fire-sheltered coastal habitats in times when most of the Cape region had been taken over by fire-prone fynbos and renosterveld shrublands since about the Miocene/Pliocene boundary and later throughout the Pleistocene. The increased aridity in the Plio-Pleistocene either prevented migration of coastal elements or increased depauperisation of the strandveld flora. On the other hand, warmer (and possibly also wetter) interglacial periods during the Pleistocene might have encouraged south-bound migration of tropical elements along the coasts—processes naturally dependent on the dynamics of coastal dune fields (accretion rates, stabilisation and abrasion rates). The glacial periods must have had an adverse effect on both south-bound migrations of the subtropical coastal thicket flora due to a decrease in temperature along the South Coast (as much as 6°C lower yearly average for the LGM) and a decrease in precipitation. West of the Caledon Mountains, the depauperisation of the strandveld ('subtropical') flora might have been further encouraged by intensification of the winter rainfall on the West Coast during the glacial periods.

We suggest that the core of the present-day strandveld expanded especially after the last major marine transgression about 1.5 mya (Compton 2004). This regression exposed major stretches of the coast (and its hinterland) and today is covered by limestone strandveld and extensive sandy plains underlain by calcrete as well as lower slopes of the granite outcrops on the West Coast. It was after this regression when extensive calcareous sand dune systems were initiated on the South Coast, opening new habitats to strandveld vegetation. The tops of the West Coast granites (Vredenburg and Saldanha Batholiths) were exposed for a long time and experienced isolation caused by marine transgressions about 5 and 1.5 mya (Compton 2004) and we suggest that it is here where the evolutionarily oldest (and most endemic-rich) form of strandveld could have developed on the West Coast.

The young age of the 'recent element' in the strandveld flora is documented in genera of typical Cape clades (Linder 2003), which contain species resulting from recent (Plio-Pleistocene) radiations. Such is the case of *Ehrharta villosa* and *E. calycina* (Verboom et al. 2003, 2004), *Thamnochortus spicigerus* and *T. erectus* (Linder & Mann 1998), *Phylica littoralis* (Richardson et al. 2000), *Pelargonium gibbosum* and *P. fulgidum* (Bakker et al. 2004), *Metalasia muricata* (Karis 1989) and *Ischyrolepis eleocharis* (H.P. Linder, personal communication).

6. Taxonomic Diversity, Endemism and Biogeographical Subdivisions

Patterns of species diversity and endemism in the Cape flora have long been the focus of research, both academic and conservation-oriented. These are well reviewed (Kruger & Taylor 1979, Campbell & Van der Meulen 1980, Bond 1983, Cowling et al. 1989, 1992, Cowling & Hilton-Taylor 1994, Goldblatt &

Manning 2000a, Linder 2003, Cowling & Procheş 2005) and analysed and compared to other regions (Cowling 1983a, 1990a, Ojeda et al. 2001, Cowling & Holmes 1992a, Cowling et al. 1996a, 1997, 2003, Wisheu et al. 2000, Cowling & Lombard 2002, Laurie & Silander 2002, Latimer et al. 2005, Etienne et al. 2006). Here we limit ourselves to patterns of biodiversity issues relevant to vegetation types of the Fynbos Biome.

6.1 Plant Diversity along Ecological Scales

The Cape Floristic Region is internationally recognised for its exceptional species diversity, which ultimately led to the recognition of the Cape flora as one of world's floristic kingdoms, on a par with much larger regions (Engler & Gilg 1919, Good 1947, Takhtajan 1986). It has also been recognised as one of 25 'hot spots' of the world's diversity (see also Mittermeier et al. 2000, Van Wyk & Smith 2001).

At the local scale, diversity in the CFR is high, without being exceptional. Where relevé data yield more plant species than tropical rainforest plots, this can be simply explained by the size of individual plants, fynbos, renosterveld and strandveld shrubs occupying less space than large forest trees. In fact, where comparisons of nonepiphytic plant diversity adjust the plot size for plant size, rainforest appears more diverse (Latimer et al. 2005). By comparison with other mediterranean-climate vegetation types, the values recorded in the CFR (10–20 species/10 m^2; 30–40 species/100 m^2; 40–120 species/1 000 m^2) are certainly not extreme (see Bond 1983, Cowling 1990a). Plots dominated by taller shrubs have generally lower diversity values compared to plots entirely dominated by smaller plants.

It is at larger spatial scales that the diversity of the CFR becomes exceptional, not only in a mediterranean-climate context, but in any context. Floristic dissimilarity along transects (often addressed as beta-diversity; Cowling & Campbell 1984, Cowling 1990a) ranging from hundreds of metres to hundreds of kilometres is impressive, with complete turnover of species between vegetation types. It has been alleged that in fynbos vegetation each mountain and valley has a flora of its own (Kruger & Taylor 1979, Cowling 1990a), although endemism levels per mountain unit are typically in the order of 1–10%. The reasons invoked to explain these astounding species numbers are multiple (Table 4.3). While spatial species packing is sufficient at finer scales, broader explanations involving habitat and climatic diversity and speciation-extinction dynamics are necessary at larger scales, most of the recorded species being endemic to fynbos vegetation (Goldblatt & Manning 2000a). Renosterveld diversity is lower in endemic species, with the exception of West Coast renosterveld, and appears to be shared more, with far less turnover, between different vegetation units. It has been suggested that long-term climatic stability was crucial in the attainment of the current levels of species diversity in the CFR (Cowling et al. 2004, Cowling & Procheş 2005).

6.2 Local and Regional Endemism

The CFR's claim to fame is that it contains almost 9 000 plant species (out of the 20 500 plant species in southern Africa: 44%) on 90 000 km^2 (or 4% of the area of the subcontinent). Almost 69% of these plant species are endemic to the CFR. This is comparable with many of the richest tropical forests and is exceptional among temperate and African floras (Goldblatt & Manning 2000a). It is the richest temperate flora in the world (Van Wyk & Smith 2001).

Most plant species in the CFR are limited to fynbos—about 7 500 of the 9 000 species, of which over 80% are endemic to the region and many (proportion is unknown, perhaps 60%) are endemic to fynbos vegetation itself. Floristically it is unique in having large numbers of species belonging to the Ericaceae (all in *Erica* with 658 species), Proteaceae (330 species), Restionaceae (318 species), Rutaceae (273 species), Polygalaceae (141 species, with *Muraltia* accounting for 100 species), Rhamnaceae (137 species, with *Phylica* accounting for 133 species), Thymelaeaceae (124 species) and Rosaceae (120 species, with *Cliffortia* accounting for 114 species). Of the 942 genera of seed plants native to the CFR, about 160 (16%) are endemic (Goldblatt & Manning 2000a).

Recent taxonomic revisions involving molecular-phylogenetic studies confirmed that five families of angiosperms (Figure 4.20) are endemic to the CFR. These are: Penaeaceae (with 23 species), Roridulaceae (2 species), and the monotypic Geissolomataceae, Grubbiaceae and Lanariaceae. All of them are confined to fynbos vegetation. Wardiaceae is the only family of mosses considered endemic to the CFR. The Bruniaceae (with 64 species in the CFR and one species in Pondoland) is near-endemic to the CFR and is also confined to fynbos. When described, the family Prioniaceae (Munro & Linder 1998) comprised only one species (*Prionium serratum*), and was considered near-endemic to the CFR (with populations in Pondoland), but it has since been placed in the Thurniaceae, with further representatives in South America (Chase et al. 2000, Goldblatt et al. 2005). The monotypic family Retziaceae previously considered endemic to the CFR (and fynbos vegetation), is now classified in the

Table 4.3 Factors and mechanisms underlying the rapid and localised diversification of the Cape flora.

	Extent	Mechanisms of fine-scale subdivision	Underlying factors
Spatial component	≈ 90 000 km^2 (small by global standards)	Landscape patchiness	Climatic diversity
			Topographical heterogeneity
			Fire-derived age mosaics
		Limited seed dispersal	Limited investment in dispersal, determined by low productivity
		Packing of individuals and species	Small plant stature and niche separation
Temporal component	5–15 million years (of relatively high climatic stability, long by global standards)	Short generation time	Connected to fire and small plant stature
		Separation between generations	Fire-driven simultaneous cohort death

Stilbaceae (Kornhall 2004). The Stilbaceae were in turn also previously considered endemic to the CFR (and fynbos vegetation), but a new circumscription of the family (Olmstead et al. 2001, Kornhall 2004) extends it to tropical Africa.

The fact that the CFR endemics belong to families such as the Ericaceae, Proteaceae, Restionaceae, Rhamnaceae and Rutaceae (all with over 90% endemism to the Cape flora; Goldblatt & Manning 2000a)—all families predominant in fynbos vegetation and not a taxonomically representative sample, suggests that fynbos vegetation types contribute significantly to overall levels of endemism. Cowling et al. (1992) have argued that most of the endemics are edaphic specialists, but this might be an artefact of their lowland sampling—the large number of local endemics presented in the descriptions of particular vegetation units as defined in this chapter suggests that on sandstone substrates at least, endemism is strongly influenced by topography. Endemics (on the lowlands) tend to be small shrubs, nonsprouting, with soil-stored, ant-dispersed seeds, and with microsymbiont-mediated nutrient uptake (Cowling et al. 1992), but whether these patterns hold within fynbos throughout the region and how they vary between local and subregional scales and the entire Fynbos Biome, is unknown.

A major problem with studies of endemism requires that detailed and comprehensive distributional data exist for the entire area. This is not generally available, the most comprehensive data being available only at a broad scale (25 x 25 km). Although it is therefore not possible to evaluate subregional or proportional endemism, it is reasonably easy to obtain data on extremely

Figure 4.20 Representatives of the endemic and near-endemic families of the Cape Floristic Region: A: *Lanaria lanata* (Lanariaceae); B: *Grubbia rosmarinifolia* (Grubbiaceae); C: *Brunia albiflora* (Bruniaceae); D: *Roridula gorgonias* (Roridulaceae); E: *Retzia capensis* (Stilbaceae); F: *Saltera sarcocolla* (Penaeaceae). Photographs: A, C–F: L. Mucina, B: D. Gwynne-Evans.

localised endemics. Preliminary comparisons of the lists of endemic taxa compiled for each of our vegetation units support the general view of endemism being greatest in the fynbos units of the southwestern mountain ranges, with a strong northern trend and much reduced richness on the eastern ranges east of the Langeberg, paralleling overall trends of species richness of taxa studied by Oliver et al. (1983) and Moline & Linder (2006). For instance, it seems that the extremely high figure for FFs 4 Cederberg Sandstone Fynbos possibly reflects the extensive collecting in the past. With more research, many of these species might be found to be more widespread in the neighbouring fynbos units. This is also supported by the high proportion of the Red Data category 'Uncertain' scored by many of the Cederberg endemics (A.G. Rebelo, unpublished data). On the other hand, the endemic accounts for well-researched areas such as Langeberg and Cape Peninsula (e.g. McDonald 1999, Helme & Trinder-Smith 2006) are probably reliable.

Renosterveld has much lower levels of endemism at the local scale (the scale of the vegetation units as defined in this chapter) than most of the units of sandstone fynbos in the western regions of the fynbos, but the endemic counts in many of the shale, granite and dolerite renosterveld units match those of the sandstone fynbos in the eastern regions as well as sand fynbos in general. When groups of ecologically analogous and geographically juxtaposed renosterveld units are considered (for instance West Coast renosterveld, South Coast renosterveld), the regional levels of endemism are considerable (N. Helme, unpublished data).

In strandveld, local endemism is considerably higher in the western units than in the strandveld units fringing the Garden Route. This is probably due to edaphic as well as occasional topographic isolation (formation of islands during marine transgressions). The endemism of the granite and limestone strandveld units of the Saldanha and Langebaan Peninsulas is comparable to those of the endemic-rich fynbos units.

A more detailed analysis of the pattern of endemism and its correlations is imminent, but it remains confounded by the lack of data for the total richness of the different vegetation units, so that the relative importance of endemism to the local and regional species pool cannot be computed.

6.3 Sources of Species Diversity and Endemism

The key to understanding the complexity of the flora and vegetation of the CFR is in understanding the sources of its extraordinary species diversity and endemism. Of the ecological factors correlated with high species diversity and endemism in the fynbos of the Langeberg (McDonald 1995), the most important is limited dispersal of seeds with a high prevalence of ant dispersal (myrmecochory) and species with no obvious adaptations to seed dispersal. Wind-dispersed species generally have broader geographical ranges. Obligate reseeding (i.e. plants incapable of resprouting) is also important, with spatially fluctuating and temporally discrete populations mediated by fire, resulting in more species. Resprouters can survive several successive fire events, and genetic intermixing between the longer-lived generations is possible, impeding speciation, so that richness approaches that of forest or thicket habitats. Consequently, reseeders usually have smaller geographical ranges than resprouters (Cowling 1987). Within the same dispersal and fire survival categories, low shrubs are generally more likely to be local endemics than other growth forms. Of all these factors, limited dispersal is particularly important, as it applies to many plant groups, irrespective of fire survival strategy and growth form (McDonald et al. 1995). This potentially contributes to the understanding of high species diversity in fynbos for groups that are fire-resistant (e.g. geophytes; Procheş et al. 2006).

From the point of view of evolutionary processes, the roots of the species diversity should be sought in the nature of speciation and extinction, and their relationship. Lately, Barraclough (2006) has summarised the causes of speciation in the Cape flora under six headings, including topographical complexity, edaphic complexity, pollinator specialisation, fire and short-dispersal distances (see Sections 2 and 4 of this chapter for more details). The patterns of extinction have not been formally analysed in the Cape, but climatic stability (see Section 2.4 for more details) has been cited most often as one of the major reasons for presumably low levels of extinction. For further analyses and insights of the intriguing hot topics forcing functions influencing the patterns of speciation and extinction, consult Dynesius & Jansson (2000), Jansson & Dynesius (2002), Linder (2003, 2005b), Linder & Hardy (2004) and Cowling & Procheş (2005).

6.4 Biogeographical Compartmentalisation

The regional distribution of endemism in the CFR was first described by Weimark (1941), who recognised 'Centres' of endemism based on the distribution of range-restricted species. These centres, updated to include a limestone centre, are still used as phytogeographical subunits of the CFR in summarising plant distributions (Goldblatt & Manning 2000a). These centres were only partly confirmed in an analytical study on major groups with fynbos endemics (Restionaceae, Ericaceae, Proteaceae, *Aspalathus*, *Muraltia*; Oliver et al. 1983), although further division between the western centres is possible (the Southwest Centre is broken down into the Peninsula Centre, West Coastal Centre, Bredasdorp Centre, and Southwest Centre proper), whereas the eastern centres (Karoo Mountain Centre, Langeberg Centre and Southeast Centre) are comparatively uniform. More advanced multivariate techniques showed even further division in the west, at least as far as the Restionaceae are concerned (Linder & Mann 1998, Linder 2001, Moline & Linder 2006). This has led to a more conservative approach by which the CFR is referred to simply as represented by a western part, rich in local endemics, and an eastern part, comparatively poor in local endemics (Cowling & Lombard 2002, Procheş et al. 2003).

Comparison of four schemes of phytogeographical subdivision of the CFR (Weimark 1941, Oliver et al. 1983, Linder & Mann 1998, Goldblatt & Manning 2000a) indeed reveals a number of important spatial congruencies, but also leaves us with many open questions, one of the most important ones being the delimitation of lowland phytochoria. However, the lowlands feature prominently in centres of endemism for the Proteaceae (Rebelo & Siegfried 1990, Cowling et al. 1992), placing them clearly within the Centres recognised by Weimark, and suggesting that Weimark's gaps were due to inadequate data. The resolution was too coarse to delimit the 'limestone floras', which are clearly a major centre of endemism (Goldblatt & Manning 2000a). At present, data for most taxa are not available at a fine enough scale (as is available for the Proteaceae) for more detailed analysis, but finer-scale data are becoming available through the geo-referencing of herbarium data and conservation projects such as CREW (Raimondo & Ebrahim 2006). It is likely that species from strandveld and renosterveld within the CFR will show different patterns.

7. Status and Threats

The degree of transformation of the Fynbos Biome vegetation types is strongly linked to topography and geographical location.

Among the 'Critically Endangered' and 'Endangered' ecosystems rank especially those of the shale, granite, ferricrete and alluvium fynbos in the Southwest Centre, converted to vineyards, fruit orchards and pine plantations to a great extent as well as those of sand fynbos, much of which has been obliterated by urban sprawl of the Cape Town metropolitan area, small holdings and alien plant invasions. All the sandstone fynbos types in the Southwest Centre rank as 'Least Threatened', highlighting the lack of transformation in the mountains. A similar pattern is apparent in the Eastern Centre, where lowland types of the granite, shale and sand fynbos are affected primarily by agriculture and afforestation, with the low-lying FFs 29 Algoa Sandstone Fynbos (endangered) due to urbanisation. However, sandstone fynbos units of the Outeniqua and Tsitsikamma Mountains are listed as 'Vulnerable' due primarily to afforestation by pines. In the other centres, it is again the lowland (both coastal and inland) and units supported by rich soil that suffered considerable transformation. Predictably, the least transformed units are the best conserved, although the northern and western extent of the Northwest Centre is poorly conserved. The distribution pattern of threatened ecosystems with the highest threat in the lowlands of the Southwest Centre is mirrored in the distribution of threatened butterflies, amphibians, reptiles and plants. Only fish species—most threatened in the Cederberg section of the Northwest Centre—differ from this pattern (Rebelo 1992a). Details of the ecosystem and conservation status are presented in the individual accounts of the vegetation types, and are summarised in Chapter 16.

The above mirrors the threats for the Fynbos Biome identified in the 1980s. In the fynbos of the lowlands, agriculture and afforestation accounted for 49% of the area transformed, with alien invasive *Acacia* species accounting for a further 36%. By contrast, in the mountains, 26% was transformed by *Hakea* and *Pinus* infestations, a further 10% by *Acacia* infestations and only 7% by agriculture and afforestation (Rebelo 1992a). These vegetation-based threats also mirror those based on Red Data plant species: alien invasive plants are the biggest threat, with agriculture and urbanisation next in line (Rebelo 2001). Among the major modern threats to sand fynbos is the increase in central pivot irrigation, mainly for potatoes, and the extraction of ground water for urban and agricultural use (A.G. Rebelo, unpublished data). The urban Cape Town metropolitan area, which has almost obliterated the FFd 5

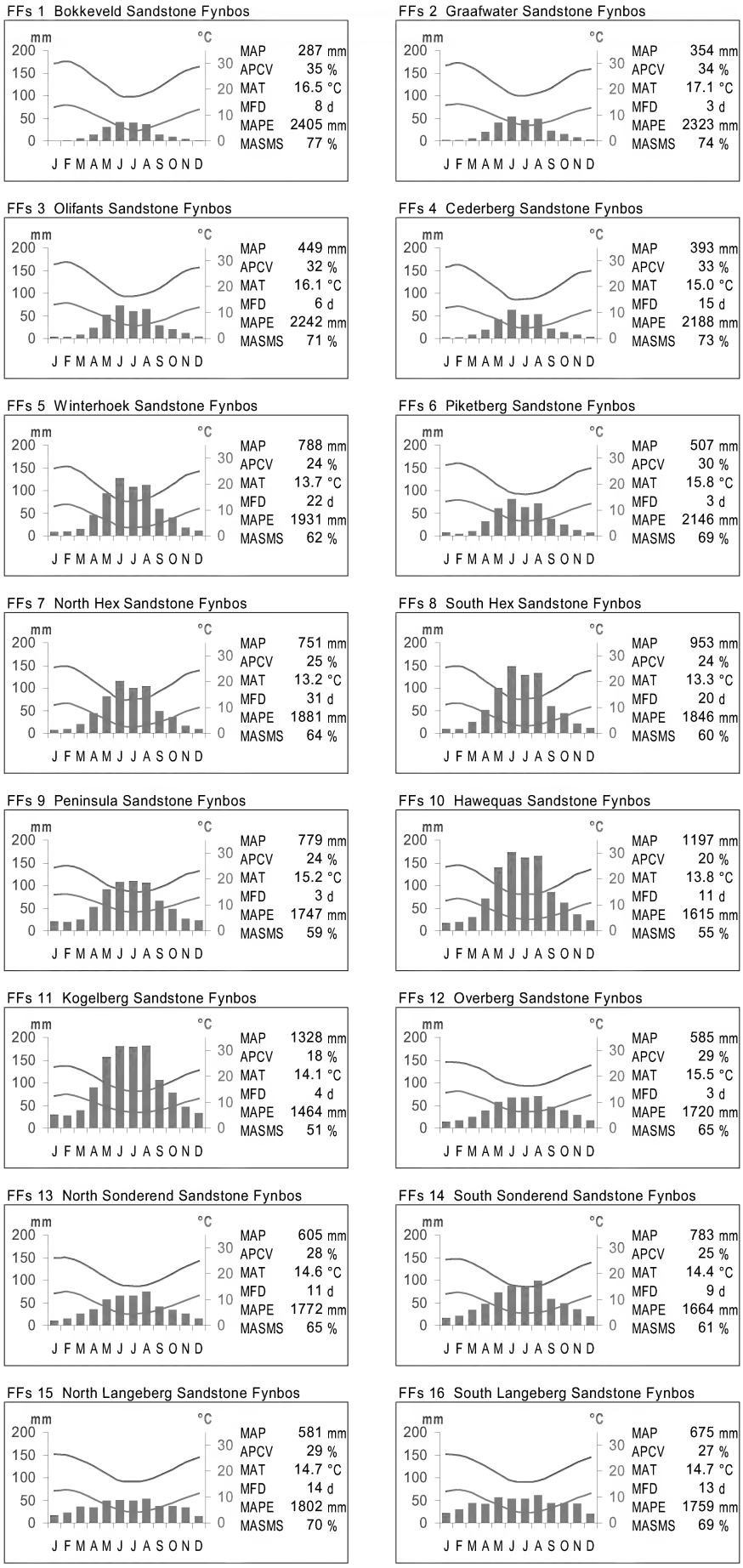

Figure 4.21 Climate diagrams of sandstone fynbos units. For the remainder of the Figure and for its full caption see the opposite page.

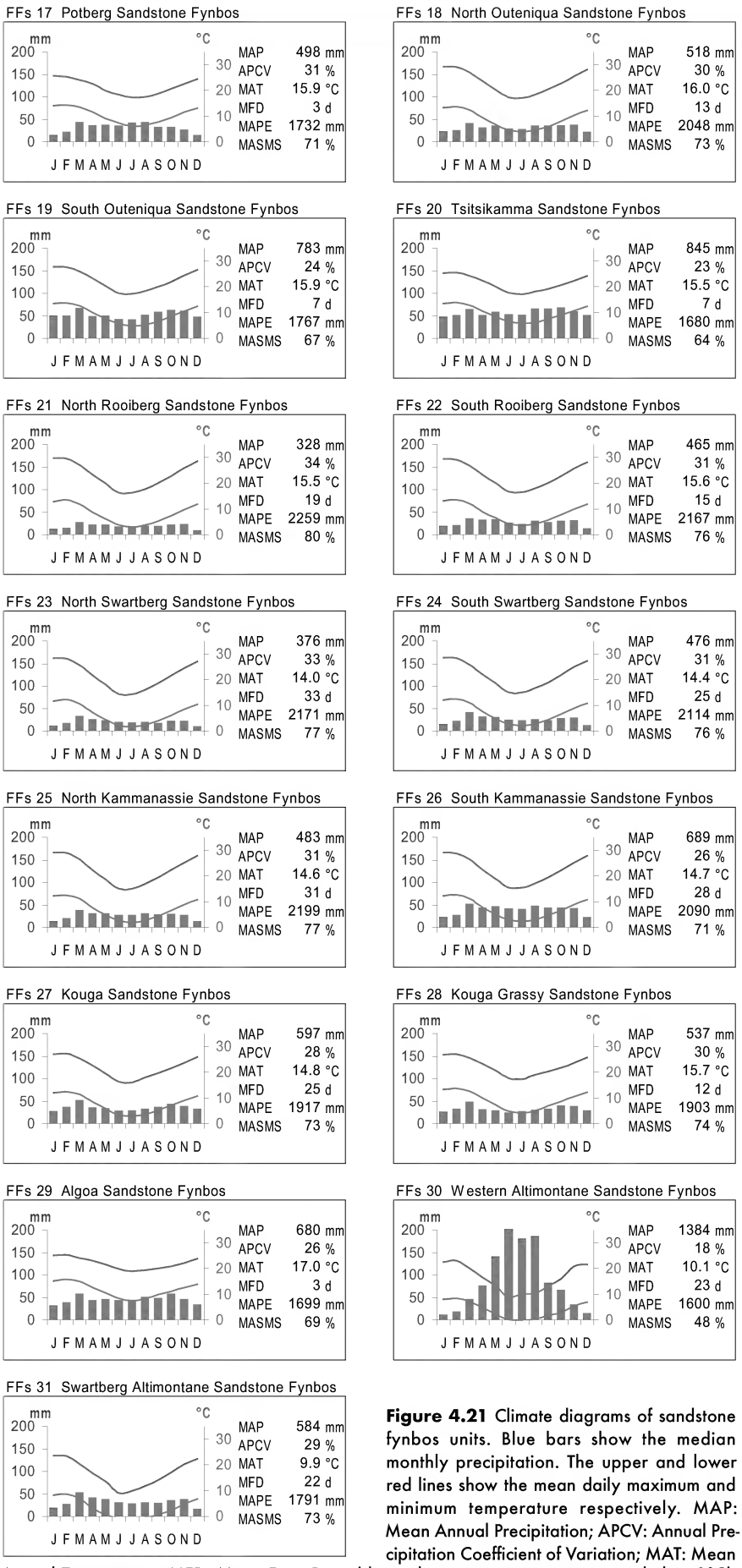

Figure 4.21 Climate diagrams of sandstone fynbos units. Blue bars show the median monthly precipitation. The upper and lower red lines show the mean daily maximum and minimum temperature respectively. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days (days when screen temperature was below 0°C); MAPE: Mean Annual Potential Evaporation; MASMS: Mean Annual Soil Moisture Stress (% of days when evaporative demand was more than double the soil moisture supply).

Cape Flats Sand Fynbos, is also a major threat to the vegetation types in its vicinity (Wood et al. 1994).

The first prescriptions for the preservation of fynbos for aesthetic and scientific value were made by Wicht (1945). These were followed by more detailed optimal strategies based on vegetation types and biogeographical regions, and iterative approaches (Rebelo 1992a). However, the network of reserves was de facto allocated on nonagricultural land as forestry land (now mainly nature conservation areas) for water catchment areas. Effectively this meant that over half of the mountains (sandstone fynbos) was conserved, but less than 3% of the lowlands was afforded any protection (Rebelo 1992a). This situation remains unchanged today.

A comprehensive action plan for fynbos and other vegetation types within the CFR has been completed (Cowling et al. 1999b) and elaborated upon both regionally and nationally (Pressey et al. 2003, Rouget et al. 2003a, b, 2004, Driver et al. 2005). In the 2000s, the Cape Action Plan for People and the Environment (CAPE) was established to effect conservation in the Fynbos Biome. Among the more significant conservation plans is the construction of 'megareserves' focused on the existing conservation areas in sandstone fynbos, but linking them to relatively unconserved renosterveld, karoo shrublands and sand fynbos of the lowlands.

Very little coastal renosterveld remains: most vegetation types are 'Critically Endangered'—with over 80% of the vegetation transformed to agriculture, chiefly for growing cereals and pastures. The inland units of renosterveld are relatively intact, although farming of these units is increasing and their status may well change over the next decade. The remnants are not representative of the communities that used to occur within renosterveld, being largely in areas that were too steep or shallow to plough mechanically, or otherwise unsuitable for agriculture (Von Hase et al. 2003).

Currently, renosterveld remnants are regularly sprayed with herbicides and insecticides—usually accidentally as drift. Fertiliser runoff also has a major influence on patches downslope of agriculture, and especially valley bottoms, river courses and seepage areas may become eutrophic. Exotic alien grasses are a major threat—apparently competing with the bulb flora. Insularisation of remnants is another major force, with many remnants predicted to experience imbalances of pollinators, seed dispersers, herbivores

and predators. Obligate reseeders and specialist (e.g. oil-bee and long-tongue fly pollination, bird seed dispersal, etc.) species will be more affected than geophytic and generalist species. Overwintering requirements and fidelity to renosterveld are little understood for insects (Rebelo 1995, Von Hase et al. 2003).

Some of these aspects, including restoration of agricultural land back to renosterveld, are currently being investigated. It appears that seeds are produced and dispersed into agricultural land, but that seedlings do not establish. However, geophytes and hemicryptophytes have short seed dispersal distances, limiting dispersal to remnants in the immediate vicinity. Both grazing and competition with agricultural grasses inhibit this establishment, but changes in soil chemistry, nursery plants and fine-scale heterogeneity after ploughing are probably paramount in affecting establishment of seedlings (Krug et al. 2004b). Unpalatable daisies (*Elytropappus, Oedera, Relhania*) or *Galenia* often form dense monospecific stands—with a near-total absence of geophytes and grasses—in old fallow lands, which appear to be stable for decades.

Invasive alien species are a major threat to biodiversity in the Fynbos Biome. Although alien organisms from many higher taxonomic groups have invaded the fynbos and renosterveld, alien plants have had by far the greatest and most direct impact on vegetation in the region.

Many plant species were introduced to the Fynbos Biome from Europe and Asia between 1653 and 1806 to fulfil the need of the Dutch colonists to cultivate a wide range of agricultural and horticultural species from their homeland and from Dutch possessions in the East. Introductions continued in the 19th century, with a concerted effort to increase the cover of trees in the tree-poor fynbos. Many tree species were introduced for forestry *sensu lato*, including plantings to supply timber and to stabilise dune sands in sand fynbos and strandveld. Such efforts resulted in very large plantings of trees, especially of species of *Acacia* and *Pinus*.

The spread and potential threat of alien plants in fynbos was first documented in the 1920s. For example, Sim (1927) noted 'the extent to which *Pinus pinaster* can take possession indicates that, if given a long enough period without check, it would probably kill out some of the endemic monotypes.'

A dozen species of trees and shrubs constitute by far the most obvious and damaging aspect of alien plant invasions. Several Australian *Acacia* species (notably *A. cyclops, A. longifolia, A. mearnsii* and *A. saligna*), three Australian *Hakea* species (*H. drupacea, H. gibbosa* and *H. sericea*), several *Pinus* species (especially *P. halepensis, P. pinaster* and *P. radiata*) have been spectacularly successful invaders in fynbos. *A. cyclops* and *Myoporum serratum* are most problematic in strandveld. The prominence of trees in the invasive flora of fynbos vegetation is unusual among mediterranean-climate regions of the world (Kruger et al. 1989) and also sets the Fynbos Biome apart from other South African biomes (Richardson et al. 1997). Many nonwoody alien plants are widespread in the Fynbos Biome, but most occur under highly disturbed conditions. Some lowland sites—primarily sand fynbos and renosterveld—are highly invaded by alien grasses (e.g. Vlok 1988), but the extent and impacts of such invasions are poorly known, although they are predicted to seriously impact on geophytes. Research into their control has recently been initiated (Musil et al. 2005).

How much of the Fynbos Biome is invaded by alien plants? Several assessments have been made, using a variety of methods. The most recent and thorough survey found that 1.6% of the CFR was covered with dense stands of woody alien plants (the same area as that under urban areas), with another 30% of the area at risk of being heavily invaded within 20 years (Rouget et al. 2004). The most detailed, species-level assessment of the extent of invasions for smaller regions within the Fynbos Biome was done for the Cape Peninsula (49 000 ha in extent). This survey showed that about 11% of the area that was not transformed by urbanisation and agriculture was under dense stands (> 25% canopy cover) of invasive alien trees and shrubs, with another 33% lightly invaded (Richardson et al. 1996). The most widespread invader was *Acacia cyclops*, occurring in both fynbos and strandveld vegetation types.

In most areas of sandstone and quartzite fynbos, the dominant invasive plants are *Hakea* and *Pinus* species. These plants are killed by fire and serotinous (with winged seeds stored in woody heat-proof cones/follicles). They initially behave much like the native shrubs, but their short juvenile periods and large reserves of highly mobile seeds buffer them against fire-induced population crashes. The prevailing nonequilibrium system is disrupted, and cyclical replacement of native overstorey shrubs is prevented. As the invaders proliferate after each fire, competition with indigenous elements is intensified, eventually leading to the local extinction of the latter as residual seed stores are depleted. There is no cyclical replacement without human intervention (such as felling of pines), and a depauperate steady-state results (Richardson & Cowling 1992). Pines and hakeas spread rapidly in fynbos, and landscapes are sometimes transformed from natural shrublands to dense alien-dominated forests over two or three fire cycles (< 50 years) (e.g. Richardson & Brown 1986). The most prominent woody invaders in sand and limestone fynbos and strandveld are several species of *Acacia*, especially *A. cyclops* and *A. saligna*. Riparian vegetation throughout the CFR is heavily invaded by alien tree species, notably *A. longifolia, A. mearnsii, Eucalyptus camaldulensis* and *Paraserianthes lophantha*, and the reed *Arundo donax* (Galatowitsch & Richardson 2005).

What is known about the impact of invasive plants in the Fynbos Biome? Dense stands of alien trees and shrubs rapidly reduce abundance and diversity of native plants at the scale of small plots. Regarding mechanisms of this attrition, studies in dense stands of *Acacia saligna* have documented the decline of soil-stored seed banks of native plants, leading to the local extinction of native species. Such invasions also greatly increase biomass, and change litter-fall dynamics and nutrient cycling. These changes have marked, and varied, effects on fire regimes. Sand fynbos has far more transient seed banks than sandstone fynbos, and nitrogen enrichment results in grassy elements replacing shrubs in sand fynbos, but not in sandstone fynbos. In the lowlands, alien annuals reduce small-scale diversity of native herbs in sand fynbos and renosterveld. Tree and shrub invasions in fynbos change many aspects of faunal communities. Studies have documented altered abundance and composition in native ant communities, with implications for the seed dispersal functions of native plants. The altered feeding behaviour of native generalist birds that disperse seeds, with likely detrimental effects on native plant species, has also been described in strandveld (see Richardson & Van Wilgen 2004 for references).

Invasive trees and shrubs also have a marked effect on the delivery of goods and services from Fynbos Biome ecosystems. In water catchment areas, besides the marked direct effects in the form of reduced stream flow, invasive alien plants have clear consequences for the ecological integrity of the catchments. For example, invasion of fynbos catchment areas increases biomass and fuel loads, leading to an increased fire hazard and soil erosion. This compromises the ability of fynbos catchments to store water for steady release throughout the year. Invaded and

burnt watersheds are denuded of soil, and runoff after rain is rapid, causing flooding, damage to property and infrastructure, and siltation. The extent and consequences of these impacts at regional scales are poorly understood. In coastal zones, stabilisation of naturally mobile sand dunes through increased plant cover and root biomass of planted and invasive *Acacia cyclops* has radically altered coastal sediment movements, leading to massive beach depletion which is threatening coastal developments along the Eastern and Western Cape coasts (see Richardson & Van Wilgen 2004 for references).

Considerable progress has been made with the management of alien plant invasions in fynbos and riparian zones of the Fynbos Biome. A milestone was the initiation of the Working for Water (WfW) programme in 1995 (Van Wilgen et al. 1996, Van Wilgen & Cowling 1998). Although successful control operations against invasive species were in place before this date, WfW provided the foundation for the initiation and, more importantly, the sustainability of control programmes at local and regional scales in the Fynbos Biome (and throughout South Africa). As its name implies, WfW initially focused largely on the control of invasive species with the specific aim of alleviating the well-documented impacts on water resources. As such, it represents a model case of the leverage of conservation action based on a scientific evaluation of the value of ecosystem services and the threats from invasive species to these services. The focus of the programme has been expanded to deal with all invasive plant species, not only those with a clear impact on water resources.

8. Action and Further Research

Although the Fynbos Biome was subject to intensive study from 1977 to 1989 under the Fynbos Biome Project (Kruger 1978, Day et al. 1979, Kruger 1979, Campbell et al. 1981, Jarman et al. 1981, Boucher & McDonald 1982, Deacon et al. 1983, Bond & Goldblatt 1984, Jarman 1984, MacDonald & Jarman 1984, Moll et al. 1984, Pierce 1984, Hall & Veldhuys 1985, Kruger et al. 1985, MacDonald et al. 1985, Cowling et al. 1987, Manders & Dicks 1987, Rebelo 1987a, Cowling 1992), it is clear that many gaps in our knowledge still exist (Huntley 1992). Thus, although fire ecology was a major research theme under the Fynbos Biome Project, and much was learned, it is still not possible to obtain figures on average fire size and differences in fire-return intervals between major mountain catchments. Although a Red Data Book was published (Hall & Veldhuys 1985), in which the presence of many rare species with small (less than 50 mature plants) isolated (with no seed dispersal) populations was documented, it is still not understood how such small populations can be self-sustaining over the time scales during which they have been observed (over 200 years). What is alarming about these deficiencies, and many others not mentioned, is that they are the cornerstone of management and monitoring of fynbos communities, especially in a world of habitat destruction, alien invasive plant infestations and global climate change. The new initiatives to complete the conservation status of species in a new Red Data List before 2006 (Foden 2006), and the Red Data List for Proteaceae (A.G. Rebelo, unpublished data), highlight these problems, but do not address them.

An understanding of the biogeography of the Fynbos Biome requires detailed inventories of species for the different vegetation types. However, due to the high species richness and turnover, the data required to map the biodiversity of the region do not exist, except for a few isolated units. We know that endemism is high for the biome—it appears to be exceptionally high also for individual mountains and vegetation types, but we do not have the data to discern patterns at any scale finer than 25 x 25 km grid units (Oliver et al. 1983), and even these are patchy. The Protea Atlas Project (Rebelo 1991), running over 10 years from 1991–2001, discovered more than 10 new taxa of Proteaceae, one of the best researched plant families of the Fynbos Biome. More importantly, it hints that much subspecific diversity exists locally that has never been adequately documented. Primary taxonomy and vegetation inventories are totally inadequate and more work is urgently needed.

Although detailed and comprehensive plans exist for the CFR (Cowling et al. 1999b, Pressey et al. 2003, Rouget et al. 2003a, b, 2004), two key assumptions require more detailed research—the long-term effects of fragmentation, and the significance of corridors. The proposed network is robust enough to cater for the inadequacies of current knowledge, but it is highly unlikely that the ambitious programmes will be comprehensively realised, especially in the lowlands. We need to understand which units and links are indispensable and which can be sacrificed. Another key assumption of the conservation plan is that invasive alien plants will be brought under control and that future invasive species will be controlled timeously. Legislation, in particular the Conservation of Agricultural Resources Act (Act No. 43 of 1983) and National Environmental Management: Biodiversity Act (Act No. 10 of 2004), to achieve this, is in effect. However, it remains to be seen whether it will work in practice. Guidelines to assessing environmental impact are also available (De Villiers et al. 2005)

Given the threat of global climate change in the region, we must be able to predict what changes will occur within the region. Unfortunately, the models are not very robust at predicting possible future rainfall patterns. Specifically, to determine the degree of habitat transformation that global climate change will effect, we have to know the annual distribution of precipitation and changes in predictability. We also have to profile which taxa and vegetation types are likely to be most affected and what mitigation (if any) is required. This must take into account that suitable alternative habitats are sometimes already occupied by sister taxa that are also under stress.

A further problem is the conservation of fynbos and renosterveld in urban areas. Current antipollution and fire legislation prevents burning of fynbos areas during peak fire periods. Mowing, which effectively destroys the communities, is preferred as an alternative to fire by some managers. Remnants become invaded with bird-dispersed strandveld species and invasive alien *Acacia* and grasses. The net effect is that prime conservation land—including some Critically Endangered vegetation units such as FFd 5 Cape Flats Sand Fynbos—are not being conserved, even though they are in conservation areas and in conservation-managed road reserves.

We know very little about renosterveld ecology, despite it having been used for livestock for over 300 years. It is unique among productive ecosystems worldwide by its very high geophytic flora. The most urgent actions required are to protect sufficient remnants to safeguard the threatened flora in the coastal renosterveld types. To this end, CAPE has identified all lowland renosterveld remnants as 'critically endangered' and 'irreplaceable' (Cowling et al. 1999b). These are flagged in regional plans as not available for conversion to agriculture or other land uses (Cowling et al. 1999b). Whether this strategy will be sufficient to prevent the further loss of these vegetation types remains to be seen. However, the remnants are too fragmented and too small for effective conservation and any effective conservation plan will require large-scale restoration of agricultural land linking these fragments into coherent units (Krug et al. 2004b).

Opportunities currently exist to reintroduce large mammals into renosterveld ecosystems in the Little Karoo and to attempt to reconstitute extinct grazing and browsing regimes. This is currently being done at various places between Barrydale and Touws River. This is an opportunity to study and recreate a lost ecosystem that should be carefully and vigorously researched.

9. Descriptions of Vegetation Units

9.1 Fynbos

Fynbos vegetation occupies 67% of the area of the Fynbos Biome and 56% of the area of the CFR. By far the most fynbos vegetation units (81%) occur on nutrient-poor sandy substrates derived from sandstone, quartzite and Tertiary sands of the Cape Fold Belt. The classification of the units into groups follows the geology.

All fynbos units contain habitats characterised as 'wetland'. These vary from seeps of varying permanency and origin, narrow restio alluvia of mountain streams, as well as fynbos peats and mires (see Sieben 2003, Sieben et al. 2004). Within these wetlands, often a single species is dominant, sometimes in zones within the wetlands, and different species may occupy apparently identical ecological niches in different geographical areas, or even in neighbouring wetlands. These communities are often localised and not detectable at the mapping scale adopted in this project (1:250 000), being best mapped at scales finer than 1:25 000 (Boucher 1978). Structurally, the fynbos wetlands are mainly restioid (dominated by *Anthochortus* and *Elegia*) or ericaceous (dominated by *Berzelia, Brunia*, *Erica*), but many are dominated by Poaceae.

In compiling species lists, two factors stand out. Firstly, the lack of constant (mono)dominance across communities. The sandstone fynbos units are usually polydominant and even their distribution patterns are not consistent across larger geographic scales. Secondly, it is often impossible to reconcile communities based on localised fine scale with those described in generalised studies. With localised studies the 'characteristic' and 'dominant' species that define broader types are often absent or insignificant. Hence, an inevitable consequence for our descriptions is that the number of communities and types recognisable is directly proportional to the number of studies undertaken, and at current levels of data, shows no sign of tapering off. Thus, even within FFs 11 Kogelberg Sandstone Fynbos, for example, it is difficult to reconcile communities from Kogelberg, Jonkershoek and Groenlandberg: even edaphically matched sites are not easily defined using only floristic composition. This is hardly surprising in the light of the renowned large beta and gamma diversity of the flora (e.g. Kruger & Taylor 1979, Cowling 1983a, 1990a, Cowling et al. 1992, Cowling & Lombard 2002, Procheş et al. 2003) and notorious functional redundancy (Cody & Mooney 1978, Cody 1986, Cowling et al. 1994a). Furthermore, most units have never had a comprehensive vegetation survey, so that species lists reflect more about levels of sampling than about ecology or biogeographical effects. There is still much basic survey research required to provide a less distorted image of the diversity of fynbos vegetation assemblages, and indeed in the Fynbos Biome on the whole.

9.1.1 Sandstone Fynbos

Sandstone Fynbos is the most extensive vegetation group in the Fynbos Biome, at 301 km^2 covering almost four times the area of the next most prominent fynbos group, Sand Fynbos, and about one third the area of the Fynbos Biome. It occurs in high-relief areas underlain by Devonian and Ordovician sandstones of the Table Mountain Group which are very resistant to erosion, except where underlain by softer sediments prone to erosion. Thus the Groot Swartberg uppermost sandstone beds (Nardouw-Baviaanskloof) have retreated northwards by a maximum of 25 km in the Swartberg, with a more typical retreat of 5–10 km from the faults along both the Worcester-Outeniqua and the Swartberg faults. The predominant east-west ranges have been stable since the break-up of Gondwana 120 mya, although some of the synclinal exposures in the Little Karoo are probably much younger. By contrast, the sandstones overlaying the West Coast were removed millions of years ago, probably largely during the Cretaceous/Pliocene, and pushed back to the Olifants fault. Remnants of this sandstone sheet still occur as Piketberg, Riebeek-Kasteel and Table Mountain—all synclinal exposures with the higher anticlines removed. Thus an area almost twice as large as the current sandstone exposure has been eroded away since the Gondwana split. Furthermore, these exposures, being anticlinal would have been higher than the current remnants, probably situated at altitudes between 1 000 and 2 000 m (see Compton 2004). The biogeographical evolutionary significance of this historical, large expanse of fynbos has not been explored.

The early post-Cretaceous would have seen a large expanse of exposed sandstone on the West Coast, and the beginnings of the large Cederberg and Kouga Mountains visible today, connected by the linear Langeberg, Riviersonderend and Swartberg scarps. These latter and the 'Karoo Island' sandstone outcrops would have become wider as erosion removed sediments from above the sandstone and decreased the steepness of the fault (South African Committee for Stratigraphy 1980).

Given these substrate patterns, the high richness of fynbos taxa in the west versus that in the east, may be the result of past differences in climate, with the westward and eastward movement of the summer-rainfall area resulting in extinction of fynbos taxa in the east. Under this scenario, the summer-rainfall zones would not have moved west of Riversdale/Swellendam (Goldblatt & Manning 2000a). During these periods, fynbos east of Swellendam would have survived only at higher altitudes: many endemics to the southern Cape sandstone fynbos areas are high-altitude species. The high relief of sandstone has resulted in most of it being above the post-Cretaceous marine incursions, with the exception of the Soetanysberg at Agulhas.

Altitudinal zonation has not been formally described for the Cape fynbos, unlike in other mediterranean-type biomes, such as the Mediterranean region itself (Rivas-Martínez 1976, 1981). Such zonation exists, and numerous bands, based both on structural and floristic types, can be observed altitudinally on both northern and southern mountain slopes. Typical idealised north-slope sequences would be encompassing asteraceous, dry restioid, proteoid, ericaceous and wet restioid fynbos, and proteoid, ericaceous and wet restioid on the southern slopes. However, these are too fine to map and have been subsumed into the geographical units. The upper limits above 1 800 m have, however, been documented (Linder et al. 1993, McDonald et al. 1993, Taylor 1996) and have been recognised in this work. Nevertheless, this is the first attempt at comprehensively mapping these zones within the Fynbos Biome. The recognition of two altimontane fynbos units is preliminary, with available data ambivalent as to their being coherent units as presented herein or subunits of the sandstone types in which they occur. The altimontane fynbos occurs on sandstone substrates, but shale bands also enter this altitudinal zone in a few places, but have been retained with the relevant shale band vegetation

unit pending more appropriate data. We refrain from using the term 'alpine' or 'subalpine' since it may invoke unjustified links to altitudinal zonation patterns of the Alps.

FFs 1 Bokkeveld Sandstone Fynbos

VT 28 Western Mountain Karoo (45%), VT 69 Macchia (41%) (Acocks 1953). Dry Mountain Fynbos (78%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (92%) (Low & Rebelo 1996). BHU 45 Bokkeveld Mountain Fynbos Complex (51%), BHU 46 Gifberg Mountain Fynbos Complex (41%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Northern and Western Cape Provinces: From the Bokkeveld Escarpment in the north along the Kobee and Matsikamma Mountains to the Gifberge between the Doring (Hantams) River (north of Nieuwoudtville) to the Doring (Tankwa) River (south of Klawer). Altitude 200–1 000 m, with the highest peak being Matsikammaberg (1 016 m).

Vegetation & Landscape Features A flat tableland, on the Bokkeveld Escarpment, elsewhere gently sloping to the east and south, without any faulting or folding in the sandstone beds. Major exposures of sandstone are at the edge of the Escarpment and where younger sediments have been removed. Topography resulting from rivers cutting through the resistant sandstone, forming deep gorges (such as Oorlogskloof) in an otherwise flat sandstone landscape. Although the shale bands of the Cedarberg Formation are largely absent, rugged 'Cederberg' landscape is formed on the eastern edge, where shale outcrops with flat-topped hills occur (and support outliers of Bokkeveld Sandstone Fynbos on their summits). Vegetation mainly closed restiolands in deeper moister sands with low, sparse shrubs that become denser with decreased restioid dominance in drier areas. Restioid, proteoid and asteraceous fynbos predominate; some waboomveld found as well.

Geology & Soils Acidic lithosol soils derived from Ordovician sandstones of the Table Mountain Group (Cape Supergroup), very variable from Glenrosa and Mispah forms to red-yellow apedal to grey regic sands or skeletal. Land types mainly Fa, Ai, Ib and Hb.

Climate MAP 160–430 mm (mean: 290 mm), peaking May to August. The most arid of the Sandstone Fynbos types. Mean daily maximum and minimum temperatures 30.8°C and 4.0°C for February and July, respectively. Frost incidence 3–10 days per year. See also climate diagram for FFs 1 Bokkeveld Sandstone Fynbos (Figure 4.21).

Important Taxa ([T]Cape thickets, [W]Wetlands) Small Trees: *Brabejum stellatifolium*[T], *Protea nitida*. Tall Shrubs: *Dodonaea viscosa* var. *angustifolia* (d), *Euryops speciosissimus* (d), *Leucadendron pubescens* (d), *Olea europaea* subsp. *africana*[T] (d), *Protea laurifolia* (d), *Aspalathus linearis*, *Diospyros glabra*[T], *Euclea lancea*[T], *E. natalensis* subsp. *capensis*[T], *Euryops tenuissimus* subsp. *tenuissimus*, *Gymnosporia buxifolia*[T], *Leucadendron procerum*, *Leucospermum praemorsum*, *Protea glabra*. Low Shrubs: *Aspalathus acocksii*, *A. pulicifolia*, *Asparagus capensis* var. *capensis*, *Athanasia microphylla*, *Ballota africana*, *Chrysocoma oblongifolia*, *Clutia alaternoides*, *Diospyros austro-africana*[T], *Erica parilis*, *E. rigidula*, *Euclea tomentosa*[T], *Felicia bergeriana*, *Gomphocarpus cancellatus*, *Leucadendron salignum*, *Leucospermum calligerum*, *Lobostemon glaucophyllus*, *Maytenus oleoides*[T], *Metalasia brevifolia*, *M. dregeana*, *M. fastigiata*, *Oedera squarrosa*, *Paranomus bracteolaris*, *Passerina truncata* subsp. *truncata*, *Pteronia divaricata*, *Serruria millefolia*, *Solanum tomentosum*, *Ursinia punctata*. Succulent Shrubs: *Braunsia maximilianii*, *Didelta spinosa*, *Euphorbia mauritanica*, *Tylecodon paniculatus*. Woody Climbers: *Asparagus aethiopicus*, *Microloma sagittatum*. Herbs: *Hemimeris racemosa*, *Rumex cordatus*, *Ursinia macropoda*. Geophytic Herbs: *Asplenium cordatum*, *Lapeirousia jacquinii*, *Melasphaerula ramosa*, *Ornithogalum maculatum*, *Romulea flexuosa*, *R. hirta*, *R. luteoflora*, *R. montana*, *R. multisulcata*[W], *R. schlechteri*[W], *R. stellata*, *R. viridibracteata*. Succulent Herbs: *Conophytum obcordellum* subsp. *obcordellum* var. *obcordellum*, *Crassula muscosa*. Graminoids: *Ehrharta longiflora*, *Ischyrolepis gaudichaudiana*, *Willdenowia incurvata*.

Endemic Taxa ([T]Cape thickets) Tall Shrubs: *Anginon ternatum*, *Hyaenanche globosa*[T]. Low Shrubs: *Leucadendron remotum* (d), *Agathosma dregeana*, *A. elata*, *Amphithalea minima*, *Aspalathus isolata*, *A. obliqua*, *A. proboscidea*, *A. venosa*, *Athanasia leptocephala*, *A. spathulata*, *Cliffortia acutifolia*, *Cullumia pectinata*, *Erica aristifolia*, *E. rusticula*, *Euryops virgatus*, *Gnidia leipoldtii*, *Gymnostephium leve*, *Leucadendron meyerianum*, *L. roodii*, *L. sheilae*, *Phylica affinis*, *P. agathosmoides*, *P. pustulata*, *Podalyria pearsonii*, *Prismatocarpus pilosus*, *Psammotropha spicata*, *Selago inaequifolia*, *Serruria lacunosa*, *Staavia phylicoides*, *Sutera longipedicellata*, *Wiborgia humilis*, *Xiphotheca canescens*. Succulent Shrubs: *Antimima insidens*, *A. lokenbergensis*, *A. paucifolia*, *Drosanthemum expersum*, *Lampranthus arenarius*, *L. globosus*, *L. neostayneri*, *L. obconicus*, *L. paucifolius*. Herbs: *Cephalaria decurrens*, *Haplocarpha parvifolia*, *Steirodiscus schlechteri*, *Ursinia dregeana*, *Zaluzianskya acrobareia*. Geophytic Herbs: *Babiana mucronata* var. *minor*, *B. sambucina* var. *longibracteata*, *B. vanzyliae*, *Bulbinella latifolia* subsp. *toximontana*, *Chlorophytum monophyllum*, *Drimia involuta*, *Eriospermum exigium*, *Geissorhiza arenicola*, *G. divaricata*, *G. subrigida*, *G. sulphurascens*, *Gladiolus mostertiae*, *G. sufflavus*, *Hessea pusilla*, *H. undosa*, *Ixia brunneobractea*, *Moraea macgregorii*, *M. vallisbelli*, *M. verecunda*, *Oxalis comptonii*, *O. oculifera*, *O. oligophylla*, *O. oreithala*, *O. porphyriosiphon*, *O. rubro-*

L. Mucina

Figure 4.22 FFs 1 Bokkeveld Sandstone Fynbos: Dry restioid fynbos with a strong fynbos thicket element, abundant *Euryops tenuissimus* and a rich annual flora on a shallow-soil sandstone plateau overlooking the Oorlogskloof Canyon on the Farm Krantzkloof, south of Nieuwoudtville (Northern Cape).

punctata, *O. suteroides*, *O. tenuis*, *Pelargonium connivens*, *P. nephrophyllum*, *P. reflexum*, *Romulea amoena*, *R. monticola*, *R. sanguinalis*, *R. sladenii*, *R. toximontana*, *Sparaxis auriculata*, *Strumaria watermeyeri*. Succulent Herbs: *Conophytum comptonii*, *C. minusculum*, *C. swanepoelianum* subsp. *rubrolineatum*. Graminoid: *Ischyrolepis longiaristata*.

Conservation Least threatened. Target 29%. Statutorily conserved (3%) in the Oorlogskloof Nature Reserve. Some 18% transformed (cultivation). The biggest threat to the original vegetation is rooibos tea farming, which results in the ploughing up of the deeper sands. The absence of aliens is very unusual among fynbos types. Erosion very low.

Remarks This is a very poorly studied type. The high endemism within this type has not been appreciated up to now.

References Van Jaarsveld (1982), L. Mucina (unpublished data), Protea Atlas Project (unpublished data).

FFs 2 Graafwater Sandstone Fynbos

VT 69 Macchia (66%), VT 34 Strandveld of the West Coast (32%) (Acocks 1953). Dry Mountain Fynbos (60%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (88%) (Low & Rebelo 1996). BHU 48 Olifants River Mountain Fynbos Complex (53%), BHU 10 Leipoldtville Sand Plain Fynbos (39%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: West Coast region, with the main block from Traval in the Olifants River Valley in the north, through areas east of Graafwater and Redelinghuys to Het Kruis (north of Piketberg) in the south. Smaller isolated patches to the west of this main body include Koeivleiberg, Klipfonteinkoppe and Muishoekberg. This fynbos type reaches the Atlantic Ocean through several unmapped patches near Elands Bay. Altitude 100–650 m. It excludes the higher mountains such as Engelsman se Berg and Swartberg (FFs 4 Cederberg Sandstone Fynbos), which are embedded in the unit.

Vegetation & Landscape Features Low mountains and gently undulating plains. Low scrub with scattered tall shrubs. Structurally it is asteraceous and scrub fynbos, with proteoid and restioid fynbos on deeper soils. In this arid environment numerous so-called 'woody' nonfynbos shrubs occur, mainly in fire-safe environments, within the fynbos matrix. This Cape thicket and scrub fynbos communities are the dominant feature of this vegetation type in rocky areas and cliffs. This is an arid version of FFs 3 Olifants Sandstone Fynbos and lacks denser and wetter vegetation. The Cape thicket communities occur in an arid facies. This type grades imperceptibly into FFd 2 Leipoldtville Sand Fynbos on the western edge, depending on sand depth and water table level.

Geology & Soils Acidic lithosol soils derived from Ordovician sandstones of the Table Mountain Group (Cape Supergroup), predominantly red-yellow apedal or Glenrosa and Mispah forms. Land types mainly Ai, Ib and Fa.

Climate MAP 200–499 mm (mean: 355 mm), peaking May to August when 70% of rain falls. Mean daily maximum and minimum temperatures 30.2°C and 6.1°C for February and July, respectively. Frost incidence 3 or 4 days per year. Mists common in winter. See also climate diagram for FFs 2 Graafwater Sandstone Fynbos (Figure 4.21).

Important Taxa ([T]Cape thickets) Small Trees: *Heeria argentea*[T] (d), *Protea nitida* (d), *Ficus cordata*, *Podocarpus elongatus*[T]. Tall Shrubs: *Diospyros ramulosa*[T] (d), *Euryops speciosissimus* (d), *Leucadendron pubescens* (d), *Olea europaea* subsp. *africana*[T] (d), *Protea laurifolia* (d), *Rhus undulata*[T] (d), *Aspalathus linearis*, *Cassine schinoides*[T], *Diospyros glabra*[T], *Euclea linearis*[T], *Leucospermum rodolentum*. Low Shrubs: *Agathosma bisulca*, *A. marifolia*, *Anthospermum galioides* subsp. *galioides*, *Aspalathus perfoliata* subsp. *phillipsii*, *Euclea tomentosa*[T], *Felicia scabrida*, *Leucadendron loranthifolium*, *Leucospermum calligerum*, *Maytenus oleoides*[T], *Metalasia fastigiata*, *Passerina truncata* subsp. *truncata*, *Rhus dissecta*[T], *Salvia lanceolata*, *Serruria decipiens*, *S. effusa*, *S. fucifolia*, *Solanum tomentosum*, *Struthiola leptantha*. Succulent Shrub: *Euphorbia mauritanica*. Woody Climbers: *Asparagus asparagoides*, *A. retrofractus*. Herb: *Arctotis cuprea* (d). Geophytic Herbs: *Geissorhiza exscapa*, *Romulea flexuosa*, *R. leipoldtii*. Succulent Herb: *Stapelia paniculata*. Graminoids: *Cannomois scirpoides*, *Ischyrolepis gaudichaudiana*.

Endemic Taxa Low Shrub: *Athanasia sertulifera*. Succulent Shrubs: *Lampranthus candidus*, *Oscularia cremnophila*, *Ruschia filipetala*. Herb: *Wahlenbergia constricta*. Geophytic Herb: *Gladiolus comptonii*.

Conservation Vulnerable. Target 29%. None conserved in statutory conservation areas. Some 28% transformed (cultivation), mainly in valley bottoms. Alien woody plants include *Acacia cyclops* and *A. saligna*. Erosion very low and low.

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Figure 4.23 FFs 2 Graafwater Sandstone Fynbos: Small sandstone outcrop with shrubby *Heeria argentea* (Anacardiaceae) overlooking Verlorenvlei Lake near Elands Bay (Western Cape).

Remark Also a feature of this vegetation type, especially on the eastern edge, are heuweltjie communities which are often dominated by succulents (*Didelta spinosa, Ruschia decurvans, Tetragonia rosea*) in the north, or thicket species (*Berkheya fruticosa, Rhus dissecta, Zygophyllum spinosum*) in the south.

References Milton (1978), Lane (1980), Boucher (1991).

FFs 3 Olifants Sandstone Fynbos

VT 69 Macchia (91%) (Acocks 1953). Mesic Mountain Fynbos (85%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (100%) (Low & Rebelo 1996). BHU 47 Cederberg Mountain Fynbos Complex (72%), BHU 48 Olifants River Mountain Fynbos Complex (19%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

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Figure 4.24 FFs 3 Olifants Sandstone Fynbos: West-facing slopes of the Cederberg below Middelberg Pass (Western Cape) covered with dense *Leucadendron*-dominated fynbos, with a small patch of waboomveld (*Protea nitida*) in the foreground.

Distribution Western Cape Province: Western Cederberg and Koue Bokkeveld Mountains from Bulshoek Dam to Keerom adjacent to Olifants River Valley and to Saron on the lower western slopes of the Vier-en-twintig Riviere (Voorberg) Mountains (but see Remark 1 below). Altitude 200–1 200 m.

Vegetation & Landscape Features Gentle to steep slopes to the Cederberg scarp as well as broad valley bottoms. The Cedarberg Shale Band (supporting vegetation of the FFb group of units) gives this landscape its distinctive flat plateau in the west and dissected back-valley to the east. This unit comprises a combination of communities tending to occur on the rocky west-facing slopes of the Cederberg where bare rock and cliffs are dominant and there is less accumulation of sand. The rock provides fire protection, resulting in the dominance of Cape thicket and asteraceous fynbos with interspersed low trees and tall shrubs forming a medium tall shrub matrix. Proteoid fynbos is most prominent on the lowermost slopes and sandy plateaus and restioid fynbos occurs on deeper sands and shallower soils.

Geology & Soils Acidic lithosol soils derived from Ordovician sandstones of the Table Mountain Group (Cape Supergroup). Land types mainly Ic, Ib and Fa.

Climate MAP 250–700 mm (mean: 450 mm), peaking May to August when 70% of rain falls. Mean daily maximum and minimum temperatures 29.6°C and 4.9°C for February and July, respectively. Frost incidence from 3–10 days per year. See also climate diagram for FFs 3 Olifants Sandstone Fynbos (Figure 4.21).

Important Taxa ([T]Cape thickets, [W]Wetlands) Small Trees: *Heeria argentea*[T], *Kiggelaria africana*[T], *Metrosideros angustifolia*[T], *Podocarpus elongatus*[T], *Protea nitida*. Tall Shrubs: *Euryops speciosissimus* (d), *Leucadendron pubescens* (d), *Olea europaea* subsp. *africana*[T] (d), *Protea laurifolia* (d), *Anisodontea bryoniifolia*, *Aspalathus aemula*, *A. linearis*, *Cassine peragua* subsp. *peragua*[T], *C. schinoides*[T], *Diospyros glabra*[T], *Dodonaea viscosa* var. *angustifolia*, *Euclea lancea*[T], *E. natalensis* subsp. *capensis*[T], *E. undulata*[T], *Euryops abrotanifolius*, *E. tenuissimus* subsp. *trifurcatus*, *Leucadendron rubrum*, *Myrsine africana*[T], *Protea glabra*, *Rhus rimosa*[T], *R. tomentosa*[T], *R. undulata*[T]. Low Shrubs: *Agathosma marifolia*, *Anthospermum galioides* subsp. *galioides*, *Aspalathus acidota*, *A. acifera*, *A. bracteata*, *A. galeata*, *A. perfoliata* subsp. *phillipsii*, *A. tridentata* subsp. *rotunda*, *Asparagus suaveolens*, *Diospyros austro-africana*[T], *Elytropappus adpressus*, *Eriocephalus africanus* var. *paniculatus*, *Leucadendron salignum*, *Maytenus oleoides*[T], *Metalasia fastigiata*, *Paranomus bracteolaris*, *Passerina truncata* subsp. *truncata*, *Phylica oleaefolia*, *Rhus dissecta*[T], *Serruria aitonii*, *S. cygnea*, *S. effusa*, *S. millefolia*, *Stoebe plumosa*, *Stachys linearis*. Succulent Shrubs: *Crassula atropurpurea* var. *watermeyeri*, *C. dejecta*, *Pelargonium alternans*. Semiparasitic Shrub: *Osyris compressa*. Geophytic Herbs: *Babiana mucronata* var. *mucronata*, *Geissorhiza confusa*, *Romulea hirta*, *R. luteoflora*, *R. saxatilis*. Graminoids: *Calopsis paniculata*, *Ehrharta calycina*, *Elegia capensis*[W], *Ischyrolepis gaudichaudiana*, *I. sieberi*, *Restio perplexus*.

Endemic Taxa Tall Shrub: *Halleria ovata*. Low Shrub: *Aspalathus ulicina* subsp. *kardouwensis*. Succulent Shrub: *Lampranthus dulcis*. Herb: *Lotononis macrocarpa*.

Conservation Least threatened. Target 29%. Statutorily conserved (23%) in the Cederberg Wilderness Area with an additional 44% protected in private conservation areas such as Winterhoek and Sederberg. Some 8% transformed (cultivation). *Pinus radiata* occurs as an alien invader in places. Erosion very low.

Remark 1 This unit was the most obviously discernable on satellite images. There are no floristic data to determine whether the Vier-en-twintig Riviere Mountains south of Piekenierskloof Pass should be included in this unit, so we deferred to the satellite images. Similarly, the boundary with FFs 2 Graafwater Sandstone Fynbos is based on satellite coverage, as there are no floristic data to suggest an alternative.

Remark 2 This unit differs from FFs 2 Graafwater Sandstone Fynbos—probably because of the higher rainfall, with Cape thicket grading into afrotemperate forest in the kloofs and valleys (the largest of these are mapped). Asteraceous fynbos is the dominant fynbos type, but even this has a high abundance of Cape thicket elements. Proteoid fynbos is most common on the lowermost slopes and on sandy plateaus, with restioid fynbos on deep sands and shallower soils.

References Boucher (1990, 1991, 1997c), Taylor (1996).

FFs 4 Cederberg Sandstone Fynbos

VT 69 Macchia (87%) (Acocks 1953). Mesic Mountain Fynbos (60%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (96%) (Low & Rebelo 1996). BHU 47 Cederberg Mountain Fynbos Complex (40%), BHU 46 Gifberg Mountain Fynbos Complex (31%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Mountains and rocky flats south of the Doring River from the Nardousberge through the Cederberg Mountains including the Pakhuisberge, Krakadouberge, Middelberg, Sneeukoppe, Tafelberg, Sneeuberg (but excluding the uppermost parts of the last-mentioned three), Breekkransberge and Sandfontein Peaks, and terminating on the Skurweberg (excluding the summit area of Sneeukop).

Also included are the higher peaks (for example, Engelsman se Berg, Swartberg and Maanberg) west of the Olifants River Valley. Substantial sections of the western parts of the central and northern Cederberg are excluded from this unit. Altitude 300 to just below the border of FFs 30 Western Altimontane Sandstone Fynbos (at about 1 800 m).

Vegetation & Landscape Features Flat to gently east- or north-sloping tableland, with steeper west-facing slopes (only upper parts in this unit)—both being rugged and dominated by rocky outcrops with gullies and flats of deep sand. Isolated mountain peaks occur and a more dissected mountainous terrain occurs in the west. The character of the Cederberg—the long, linear step or plateau that dominates the landscape between the upper and lower blocks of rugged sandstone—is given by the Cedarberg Shale Band (see FFb 1 Northern Inland Shale Band Vegetation). Vegetation consists of closed restiolands on deeper moister sands, with low, sparse shrubs that become denser and Restionaceae less dominant in the drier areas. Structurally it is predominantly asteraceous, restioid and proteoid fynbos. North of Pakhuis Pass towards the Doring River this grades through asteraceous fynbos to SKv 1 Doringrivier Quartzite Karoo.

Geology & Soils Acidic lithosol soils derived from Ordovician sandstones of the Table Mountain Group (Cape Supergroup). Land types mainly Ic, Ib, Ai and Fa.

Climate MAP 180–600 mm (mean: 395 mm), peaking May to August. Mean daily maximum and minimum temperatures 28.4°C and 4°C for February and July, respectively. Frost incidence 3–30 days per year. See also climate diagram for FFs 4 Cederberg Sandstone Fynbos (Figure 4.21).

Important Taxa ([T]Cape thickets, [W]Wetlands) Small Trees: *Protea nitida* (d), *Aspalathus pendula*. Tall Shrubs: *Cassine schinoides*[T] (d), *Diospyros glabra*[T] (d), *Heeria argentea*[T] (d), *Leucadendron pubescens* (d), *Maytenus oleoides*[T] (d), *Metalasia densa* (d), *Metrosideros angustifolia*[T] (d), *Morella serrata* (d), *Olea europaea* subsp. *africana*[T] (d), *Phylica buxifolia* (d), *Podocarpus elongatus*[T] (d), *Protea glabra* (d), *P. laurifolia* (d), *Rhus undulata*[T] (d), *Anisodontea bryoniifolia*, *Aspalathus aemula*, *A. linearis*, *Dodonaea viscosa* var. *angustifolia*, *Euclea lancea*[T], *E. linearis*[T], *E. undulata*[T], *Euryops speciosissimus*, *E. tenuissimus* subsp. *tenuissimus*, *E. tenuissimus* subsp. *trifurcatus*, *Hypocalyptus sophoroides*, *Leucadendron rubrum*, *Montinia caryophyllacea*, *Myrsine africana*[T], *Protea magnifica*, *P. repens*, *Rhus rimosa*[T]. Low Shrubs: *Cliffortia ruscifolia* (d), *Diosma acmaeophylla* (d), *D. meyeriana* (d), *Elytropappus adpressus* (d), *Erica maximiliani* (d), *Eriocephalus africanus* var. *africanus* (d), *Metalasia agathosmoides* (d), *Passerina truncata* subsp. *truncata* (d), *Phylica rigidifolia* (d), *Rafnia diffusa* (d), *Stoebe intricata* (d), *S. plumosa* (d), *Aspalathus acifera*, *A. acocksii*, *A. altissima*, *A. argyrella*, *A. bodkinii*, *A. bracteata*, *A. ciliaris*, *A. divaricata* subsp. *divaricata*, *A. filicaulis*, *A. galeata*, *A. heterophylla*, *A. lanceifolia*, *A. perfoliata* subsp. *phillipsii*, *A. pinea* subsp. *pinea*, *A. retroflexa* subsp. *angustipetala*, *A. rupestris*, *A. shawii* subsp. *shawii*, *A. tridentata* subsp. *rotunda*, *A. tridentata* subsp. *tridentata*, *A. villosa*, *Asparagus lignosus*, *Athanasia flexuosa*, *A. microphylla*, *Cliffortia hexandra*, *Clutia alaternoides*, *Dolichothrix ericoides*, *Elytropappus gnaphaloides*, *E. rhinocerotis*, *Erica daphniflora*, *E. parilis*, *E. plumosa*, *Eriocephalus ericoides* subsp. *ericoides*, *Euryops othonnoides*, *E. wageneri*, *Felicia scabrida*, *Gnidia geminiflora*, *Leucadendron arcuatum*, *L. brunioides* var. *brunioides*, *L. nitidum*, *L. salignum*, *Leucospermum tottum*, *Linconia cuspidata*, *Lobostemon glaucophyllus*, *Metalasia dregeana*, *Muraltia pillansii*, *Oedera sedifolia*, *O. squarrosa*, *Paranomus bracteolaris*, *Passerina truncata* subsp. *monticola*, *Pelargonium laevigatum*, *Phylica alpina*, *P. ambigua*, *P. insignis*, *P. leipoldtii*, *P. odorata*, *P. oleaefolia*, *P. rigida*, *Prismatocarpus brevilobus*, *Protea acaulos*, *P. pendula*, *P. recondita*, *P. witzenbergiana*, *Pteronia camphorata*, *P. incana*, *Rhus rosmarinifolia*[T], *Serruria aitonii*, *Sorocephalus lanatus*, *Stachys linearis*, *Stoebe aethiopica*, *S. fusca*, *S. leucocephala*, *Tephrosia capensis*, *Ursinia pilifera*, *U. punctata*, *Zyrphelis pilosella*. Succulent Shrubs: *Crassula dejecta* (d), *Ruschia dichroa* (d), *Antimima dasyphylla*, *Crassula atropurpurea* var. *watermeyeri*, *Othonna parviflora*. Pseudocarnivorous Shrub: *Roridula dentata*. Herbs: *Centella recticarpa*, *Indigofera humifusa*, *Lebeckia longipes*, *Ursinia macropoda*. Geophytic Herbs: *Babiana mucronata* var. *mucronata*, *Geissorhiza aspera*, *G. bolusii*[W], *G. confusa*, *G. exscapa*, *G. juncea*, *G. leipoldtii*, *G. longifolia*, *G. parva*, *G. scillaris*, *G. umbrosa*, *G. unifolia*, *Romulea biflora*, *R. flexuosa*, *R. leipoldtii*, *R. montana*, *R. schlechteri*[W], *R. stellata*, *R. viridibracteata*. Succulent Herbs: *Senecio crassulaefolius*, *Stapelia cedrimontana*. Carnivorous Herb: *Utricularia bisquamata*[W]. Graminoids: *Cannomois parviflora* (d), *Cyathocoma ecklonii*[W] (d), *Ehrharta calycina* (d), *E. villosa* var. *villosa* (d), *Elegia asperiflora* (d), *E. filacea* (d), *E. macrocarpa* (d), *Ficinia dunensis* (d), *F. nigrescens* (d), *Hypodiscus neesii* (d), *Ischyrolepis curviramis* (d), *I. gaudichaudiana* (d), *I. monanthos* (d), *I. nana* (d), *I. ocreata* (d), *I. sieberi* (d), *I. virgea* (d), *Merxmuellera arundinacea* (d), *Pentaschistis eriostoma* (d), *Restio filiformis* (d), *R. occultus* (d), *R. perplexus* (d), *Staberoha aemula* (d), *Tetraria cuspidata* (d), *T. ustulata* (d), *Thamnochortus platypteris* (d), *Willdenowia arescens* (d), *W. incurvata* (d), *Andropogon appendiculatus*, *Calopsis paniculata*, *Chrysitrix junciformis*, *Ehrharta ramosa* subsp. *aphylla*, *Elegia capensis*[W], *Epischoenus dregeanus*, *E. gracilis*, *Ficinia bul-*

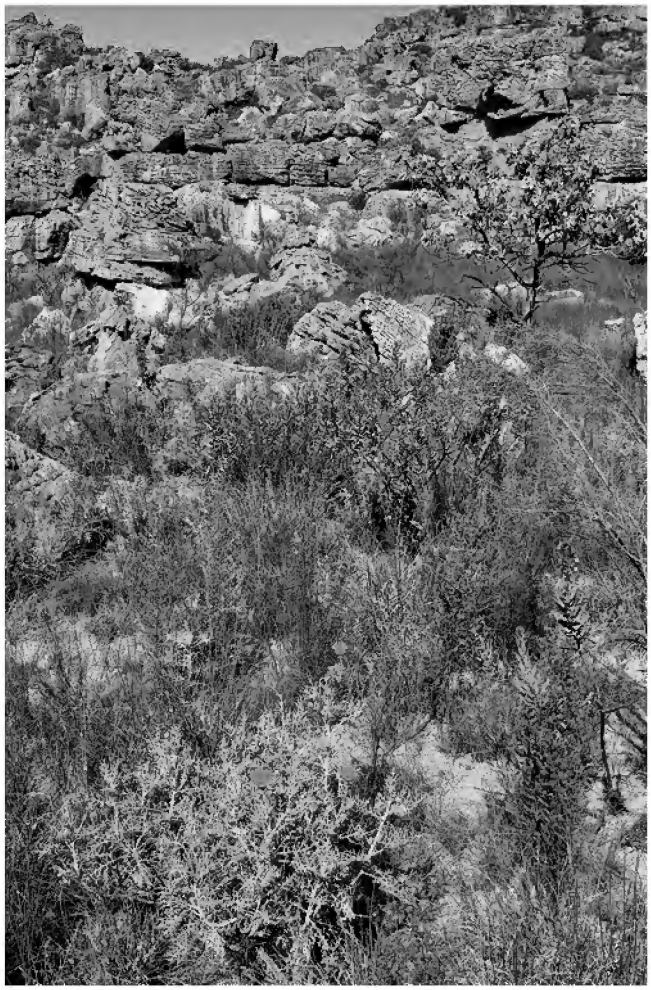

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Figure 4.25 FFs 4 Cederberg Sandstone Fynbos: Dry restioid fynbos with *Arctotis revoluta* (Asteraceae) in the foreground and a small tree of *Protea nitida* against a background of craggy formations of Nardouw sandstone, Pakhuis Pass near Clanwilliam (Western Cape).

bosa, *Ficinia* sp. nov. ('*petitiana*'), *Fuirena hirsuta*[W], *Hypodiscus laevigatus*, *Juncus capensis*, *Pentaschistis densifolia*, *Restio strobolifer*, *Tetraria compar*, *T. nigrovaginata*, *T. triangularis*, *Thamnochortus schlechteri*.

Endemic Taxa ([W]Wetlands) Small Tree: *Widdringtonia cedarbergensis* (d). Tall Shrubs: *Aspalathus decora*, *Leucospermum reflexum*[W], *Paranomus tomentosus*. Low Shrubs: *Acmadenia bodkinii*, *A. flaccida*, *A. patentifolia*, *A. rourkeana*, *A. tenax*, *A. tetracarpellata*, *Agathosma aemula*, *A. bathii*, *A. bicolor*, *A. conferta*, *A. dentata*, *A. distans*, *A. esterhuyseniae*, *A. humilis*, *A. krakadouwensis*, *A. longicornu*, *A. pattisoniae*, *A. pubigera*, *A. rubricaulis*, *A. salina*, *A. stilbeoides*, *A. viviersii*, *Amphithalea cedarbergensis*, *Anisodontea gracilis*, *Aspalathus comptonii*, *A. polycephala* subsp. *lanatifolia*, *A. polycephala* subsp. *polycephala*, *A. polycephala* subsp. *rigida*, *A. tridentata* subsp. *fragilis*, *Athanasia calophylla*, *Athrixia crinita*, *Berkheya dregei*, *Chrysocoma candelabrum*, *Erica aspalathoides*, *E. cavartica*, *E. cederbergensis*, *E. cedromontana*, *E. cernua*[W], *E. eugenea*, *E. hanekomii*, *E. incarnata*, *E. lateriflora*, *E. senilis*, *Euchaetis glomerata*, *Heliophila cedarbergensis*, *Hermannia helicoidea*, *Lachnaea leipoldtii*, *L. naviculifolia*, *Leucadendron bonum*, *L. concavum*, *L. dubium*, *L. sericeum*, *Leucospermum spathulatum* (Cederberg form), *Liparia congesta*, *Macrostylis hirta*, *Manulea rigida*, *Metalasia albescens*, *Pelargonium caespitosum*, *Pharnaceum rubens*, *Phylica barbata*, *P. fruticosa*, *P. maximiliani*, *P. plumigera*, *Phyllosma capensis*, *Polygala brachyphylla*, *Prismatocarpus altiflorus*, *P. pauciflorus*, *Protea cryophila*, *P. inopina*, *Psammotropha anguina*, *Rafnia globosa*, *Raspalia staavioides*, *Selago cedrimontana*, *S. dolichonema*, *S. dregeana*, *S. pustulosa*, *Serruria flava*, *S. leipoldtii*, *Struthiola lineariloba*, *Trieenea lanciloba*, *T. lasiocephala*, *T. laxiflora*, *Ursinia subflosculosa*, *Zyrphelis ecklonis*. Succulent Shrubs: *Antimima brevicarpa*, *A. distans*, *A. minutifolia*, *A. tuberculosa*, *Cephalophyllum parvulum*, *Drosanthemum longipes*, *D. pulchellum*, *Erepsia distans*, *Esterhuysenia drepanophylla*, *Lampranthus cyathiformis*, *L. longistamineus*, *L. lunulatus*, *L. macrostigma*, *L. pakhuisensis*, *L. staminodiosus*, *L. virgatus*, *Octopoma rupigenum*, *Oscularia cedarbergensis*, *O. compressa*, *O. ornata*, *O. thermarum*, *Phyllobolus viridiflorus*, *Ruschia bolusiae*, *R. cedarbergensis*, *R. intricata*, *R. lapidicola*, *R. misera*, *R. radicans*, *R. rariflora*, *R. rigidicaulis*, *R. triflora*. Herbs: *Annesorhiza filicaulis*, *Arctotis adpressa*, *Centella lasiophylla*, *C. ternata*, *Cotula montana*, *Galium monticolum*, *Haplocarpha oocephala*, *Helichrysum aureofolium*, *Lobelia comptonii*, *Manulea adenodes*, *M. arabidea*, *M. montana*, *Monopsis acrodon*, *Oligothrix gracilis*, *Oncosiphon intermedium*, *Pharnaceum serpyllifolium*, *Phyllopodium pubiflorum*, *Polycarena exigua*, *P. nardouwensis*, *Pseudoselago guttata*, *P. humilis*, *Sutera subsessilis*, *Trieenea elsiae*, *T. schlechteri*, *T. taylorii*, *Wahlenbergia adamsonii*, *W. brachycarpa*, *Zaluzianskya glandulosa*. Geophytic Herbs: *Apodolirion cedarbergense*, *Aristea rupicola*, *A. singularis*, *Babiana auriculata*, *B. cedarbergensis*, *B. geniculata*, *B. unguiculata*, *Disa cedarbergensis*[W], *Disperis bolusiana* subsp. *macrocorys*, *Geissorhiza cedarmontana*, *G. ciliatula*, *G. minuta*[W], *G. stenosiphon*, *Gladiolus buckerveldii*, *G. delpierrei*, *G. taubertianus*, *Haemanthus nortieri*, *Hesperantha elsiae*, *Lachenalia margaretae*, *L. maximiliani*, *Moraea autumnalis*, *M. barkerae*, *M. cedarmonticola*, *M. maximiliani*, *M. patens*, *Oxalis aridicola*, *O. leipoldtii*, *O. oreophila*, *O. petiolulata*, *O. phloxidifora*, *O. simplex*, *O. xantha*, *Romulea cedarbergensis*, *R. sulphurea*, *R. vinacea*, *Sparaxis caryophyllacea*, *Tritoniopsis latifolia*, *T. nemorosa*. Succulent Herbs: *Crassula elsieae*, *Tetragonia galenioides*. Parasitic Herb: *Harveya sulphurea*. Graminoids: *Askidiosperma albo-aristatum*, *Ficinia cedarbergensis*, *F. mucronata*, *Ischyrolepis setiger*, *Restio brunneus*.

Conservation Least threatened. Target 29%. Statutorily conserved (17%) in the Cederberg Wilderness Area, with 29% enjoying protection in private reserves such as Sederberg and Koue Bokkeveld. However, in both the north and south distinctive communities are not conserved. Some 15% transformed, mainly for cultivation of rooibos and vineyards. *Pinus radiata* is a serious alien intruder. Erosion very low.

Remarks Cederberg Sandstone Fynbos has been mapped from the watershed eastwards, based on satellite images. The Krakadouwberg-Welbedacht area was very well sampled by Taylor (1996), but other areas are poorly known. The number of endemics is extraordinary high for the size and location of this type. It is possible that they may occur in neighbouring types as well, but currently they appear to be confined to this type. The boundary between this unit and FFs 3 Olifants Sandstone Fynbos can only be very approximate at this stage.

References Kruger (1979), Mustart et al. (1993), Taylor (1996), Boucher (1997c, 1999d), Van Rooyen et al. (1999).

FFs 5 Winterhoek Sandstone Fynbos

VT 69 Macchia (100%) (Acocks 1953). Mesic Mountain Fynbos (89%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (90%) (Low & Rebelo 1996). BHU 51 Groot Winterhoek Mountain Fynbos Complex (59%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Groot Winterhoek Mountains from Dasklip Pass in the north to Saronsberg and

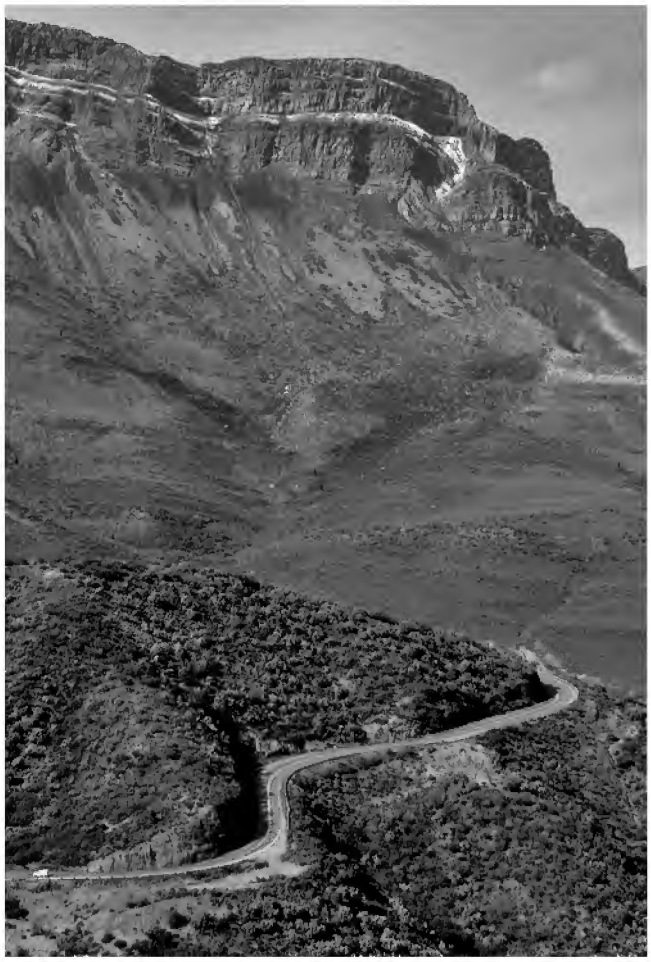

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Figure 4.26 FFs 5 Winterhoek Sandstone Fynbos: Western slopes of the Waboomberg covered with extensive sandstone screes—a view from Gydo Pass north of Ceres (Western Cape). The dominant vegetation below the cliffs is FFh 1 Kouebokkeveld Shale Fynbos with extensive waboomveld (*Protea nitida*-dominated fynbos) in the foreground along the pass.

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Figure 4.27 FFs 5 Winterhoek Sandstone Fynbos: Proteoid fynbos with stands of *Protea punctata* in a matrix of restios on the Skurweberg, north of Ceres (Western Cape).

Nuwekloof Pass, including the Witsenberg and Skurweberge (west of Gydo Pass) (which encircle a large patch of FFh 1 Kouebokkeveld Shale Fynbos in the Agter-Witsenberg) to the vicinity of Ceres and including the Gydo, Waboom, Vaalkloof and Houdenbek Mountains in the east. Altitude 350–1 800 m. (The highest peaks of the Groot Winterhoek Mountains bear vegetation of FFs 30 Western Altimontane Sandstone Fynbos.)

Vegetation & Landscape Features Moderately undulating high plain in the west, with rugged high peaks in the south and southeast, and two linear parallel north-south high mountains in the east, dissected by the Olifants River Valley. The eastern blocks are relatively flat, south- and north-sloping, dissected tablelands. Vegetation is mainly closed restioland in deeper moister sands, with low, sparse shrubs that become denser and restios less dominant in the drier habitats. Proteoid and ericaceous fynbos are found on higher slopes while asteraceous fynbos is more common on lower slopes. Cape thicket is prominent on the lowest slopes.

Geology & Soils Acidic lithosol soils derived from Ordovician sandstones of the Table Mountain Group (Cape Supergroup). Land types mainly Ic, Fa and Ib.

Climate MAP 370–1 350 mm (mean: 790 mm), peaking markedly May to August. Southeasterly cloud occasionally brings heavy mist precipitation at higher altitudes in summer. This is the wettest of the northern Sandstone Fynbos types. Mean daily maximum and minimum temperatures 26.7°C and 3.1°C for February and July, respectively. Frost incidence 10–30 days per year. See also climate diagram for FFs 5 Winterhoek Sandstone Fynbos (Figure 4.21).

Important Taxa ([W]Wetlands) Small Tree: *Protea nitida* (d). Tall Shrubs: *Protea repens* (d), *Aspalathus aemula*, *A. linearis*, *Euryops abrotanifolius*, *E. serra*, *E. speciosissimus*, *E. tenuissimus* subsp. *trifurcatus*, *Leucadendron rubrum*, *Metalasia muraltiifolia*, *Protea laurifolia*. Low Shrubs: *Ursinia pinnata* (d), *Aspalathus argyrella*, *A. commutata*, *A. filicaulis*, *A. perfoliata* subsp. *perfoliata*, *A. perforata*, *A. pinea* subsp. *pinea*, *A. retroflexa* subsp. *angustipetala*, *A. rugosa*, *A. rupestris*, *A. ulicina* subsp. *ulicina*, *A. villosa*, *Erica parilis*, *E. rigidula*, *E. tenuis*, *E. totta*, *Euryops rupestris* var. *dasycarpus*, *Leucadendron arcuatum*, *L. glaberrimum* subsp. *erubescens*, *L. salignum*, *Metalasia rogersii*, *Paranomus lagopus*, *Passerina nivicola*, *Phylica chionocephala*, *P. obtusifolia*, *Protea acaulos*, *P. effusa*, *P. nana*, *P. pendula*, *P. piscina*, *P. pityphylla*, *P. recondita*, *P. witzenbergiana*, *Serruria cygnea*, *S. effusa*, *Sorocephalus lanatus*, *Spatalla caudata*[W], *Ursinia coronopifolia*, *U. punctata*. Pseudocarnivorous Shrub: *Roridula dentata*. Herb: *Ursinia sericea*. Geophytic Herbs: *Geissorhiza bolusii*[W], *G. intermedia*, *G. ovalifolia*, *G. ovata*, *G. parva*, *G. ramosa*, *G. scillaris*, *Romulea saxatilis*. Graminoids: *Cyathocoma ecklonii*[W], *Elegia macrocarpa*.

Endemic Taxa ([W]Wetlands) Low Shrubs: *Agathosma alligans*, *A. cordifolia*, *Aspalathus corniculata*, *A. empetrifolia*, *A. fasciculata*, *A. juniperina* subsp. *gracilifolia*, *A. suaveolens*, *A. sulphurea*, *Capelio tomentosa*, *Disparago gongylodes*, *Erica amalophylla*, *E. greyi*, *E. irrorata*, *E. leucosiphon*, *Euchaetis ericoides*, *E. esterhuyseniae*, *Euryops longipes* var. *lasiocarpus*, *Lachnaea villosa*, *Leucadendron diemontianum*, *L. gydoense*, *Macrostylis barbigera*, *M. ramulosa*, *Metalasia juniperoides*, *M. serrulata*, *Pelargonium capillare*, *Phylica alticola*, *P. bolusii*, *P. nervosa*, *P. salteri*, *P. trachyphylla*, *Prismatocarpus implicatus*, *Selago valliscitri*, *Serruria reflexa*, *Sheilanthera pubens*, *Sorocephalus scabridus*, *Spatalla tulbaghensis*, *Stoebe montana*, *Thamnea hirtella*, *Thesmophora scopulosa*, *Wahlenbergia brachyphylla*. Succulent Shrubs: *Lampranthus antonii*, *L. microsepalus*, *Oscularia guthriae*, *Ruschia intermedia*. Herbs: *Centella umbellata*, *Globulariopsis obtusiloba*, *Lotononis laticeps*, *Pseudoselago quadrangularis*, *Steirodiscus gamolepis*, *Trieenea frigida*, *Vellereophyton felinum*, *V. lasianthum*, *Zaluzianskya isanthera*. Geophytic Herbs: *Disa introrsa*, *Geissorhiza esterhuyseniae*, *Romulea albomarginata*, *Tritoniopsis lesliei*[W]. Succulent Herb: *Crassula alcicornis*. Graminoids: *Carpha schlechteri*, *Isolepis minuta*.

Conservation Least threatened. Target 29%. Statutorily conserved (24%) in the Grootwinterhoek Wilderness Area, with an additional 59% protected in private reserves such as Koue Bokkeveld and Winterhoek. Only 5% transformed (cultivation: protea nurseries and fruit orchards). Aliens *Pinus radiata*, *P. pinaster* and *Hakea sericea* are scattered. Erosion very low.

Remarks Groot Winterhoek is a poorly studied region, mainly due to difficulty of access. The fynbos on quartzite of Gydoberg, Waboomsberg and Houdenbeksberg have been included in this type based on the distribution of proteas—these are wetter than normal quartzite and their floras appear to be more similar to Winterhoek Sandstone Fynbos than to FFq 2 Swartruggens Quartzite Fynbos.

References Boucher (1987, 1990, 1996a, 1997c, 2000), Rourke (1993).

FFs 6 Piketberg Sandstone Fynbos

VT 69 Macchia (51%), VT 47 Coastal Macchia (27%), VT 46 Coastal Renosterbosveld (20%) (Acocks 1953). Mesic Mountain Fynbos (84%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (86%) (Low & Rebelo 1996). BHU 50 Piketberg Mountain Fynbos Complex (86%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Mainly on the Piketberg Mountains in a triangle formed by Aurora, Het Kruis and the town of Piketberg but also on isolated hills to the north of the mountain including Driefonteinberg, Tiernesberg, Dassieberg

and Klein Tafelberg. The low altitude boundary lies at 100 m, while the highest coincides with the highest peak of the Piketberg (Sebrakop 1 458 m).

Vegetation & Landscape Features Large inselberg built of slowly eroding hard rocks towering over the surrounding sandy and shale plains of the West Coast. Mostly steep slopes, with some small plateaus and peaks. Vegetation is mainly closed restioland on deeper moister sands with low, sparse shrubs that become denser and the restios less pronounced in the drier habitats. Asteraceous and proteoid fynbos predominate in rocky areas, and Cape thicket is prominent as well.

Geology & Soils Acidic lithosol soils derived from Ordovician sandstones of the Table Mountain Group (Cape Supergroup). Land type mainly Ib.

Climate MAP 320–860 mm (mean: 510 mm), peaking May to August. Mean daily maximum and minimum temperatures 28.1°C and 5.6°C for February and July, respectively. Frost incidence 2–4 days per year. See also climate diagram for FFs 6 Piketberg Sandstone Fynbos (Figure 4.21).

Important Taxa ([T]Cape thickets, [W]Wetlands) Small Trees: *Heeria argentea*[T] (d), *Kiggelaria africana*[T] (d), *Podocarpus elongatus*[T] (d), *Aspalathus pendula*, *Brabejum stellatifolium*[T], *Metrosideros angustifolia*[T], *Protea nitida*. Tall Shrubs: *Cassine schinoides*[T] (d), *Halleria lucida*[T] (d), *Leucadendron rubrum* (d), *Metalasia densa* (d), *Olea europaea* subsp. *africana*[T] (d), *Protea laurifolia* (d), *P. repens* (d), *Cunonia capensis*[T], *Euryops speciosissimus*, *Maytenus acuminata*[T], *Rhus angustifolia*[T]. Low Shrubs: *Asparagus rubicundus* (d), *Cliffortia ruscifolia* (d), *Elytropappus gnaphaloides* (d), *E. rhinocerotis* (d), *Erica nudiflora* (d), *Eriocephalus africanus* var. *africanus* (d), *Leucospermum calligerum* (d), *Maytenus oleoides*[T] (d), *Passerina truncata* subsp. *truncata* (d), *Phylica villosa* (d), *Serruria aitonii* (d), *Stoebe plumosa* (d), *Aspalathus acidota*, *A. altissima*, *A. bracteata*, *A. perfoliata* subsp. *phillipsii*, *Diosma hirsuta*, *Elytropappus glandulosus*, *Erica parilis*, *E. phillipsii*, *Leucadendron glaberrimum* subsp. *erubescens*, *L. loranthifolium*, *L. salignum*, *Metalasia fastigiata*, *Oedera squarrosa*, *Phylica cylindrica*, *Protea acaulos*, *P. piscina*, *P. recondita*, *Rhus rosmarinifolia*[T], *Sorocephalus capitatus*, *Trichocephalus stipularis*, *Ursinia rigidula*. Succulent Shrub: *Aloe glauca*. Woody Climber: *Asparagus retrofractus*. Herb: *Syncarpha canescens*. Geophytic Herbs: *Adiantum capillus-veneris*[W], *Blechnum capense*, *Osmunda regalis*[W], *Othonna lingua*. Succulent Herbs: *Stapelia cedrimontana*, *S. paniculata*. Graminoids: *Elegia macrocarpa* (d), *Ischyrolepis gaudichaudiana* (d), *I. sieberi* (d), *Calopsis paniculata*, *Elegia capensis*[W], *Ischyrolepis capensis*, *Staberoha distachyos*, *Tetraria ustulata*, *Willdenowia arescens*, *W. incurvata*.

Endemic Taxa Tall Shrub: *Psoralea peratica*. Low Shrubs: *Acmadenia macradenia*, *Agathosma capitata*, *Aspalathus chrysantha*, *A. complicata*, *A. glossoides*, *A. latifolia*, *Erica piquetbergensis*, *Euchaetis tricarpellata*, *Euryops pectinatus* subsp. *lobulatus*, *Hermannia cordifolia*, *H. hispidula*, *Leucadendron discolor*, *Leucospermum profugum*, *Manulea ovatifolia*, *Muraltia arachnoidea*, *Phylica piquetbergensis*, *Rafnia inaequalis*. Succulent Shrubs: *Erepsia pillansii*, *Lampranthus acrosepalus*, *L. falciformis*, *L. martleyi*, *L. matutinus*, *L. profundus*, *L. subtruncatus*, *Oscularia piquetbergensis*, *O. prasina*, *O. primiverna*, *Ruschia strubeniae*. Herbs: *Corymbium theileri*, *Globulariopsis pumila*, *Lotononis densa* subsp. *congesta*, *Nemesia acornis*. Geophytic Herbs: *Aristea fimbriata*, *Bobartia orientalis* subsp. *occidentalis*, *Geissorhiza brevituba*, *Gladiolus insolens*, *Ixia splendida*, *Tritonia lancea*.

Conservation Least threatened. Target 29%. None conserved in statutory conservation areas and only 4% protected in private nature reserves. Some 17% transformed (cultivation: fruit orchards on deeper soils). *Acacia saligna* scattered over large area. The most transformed 'mountain fynbos' unit in the biome. Erosion very low.

Remarks The lower slopes have affinities with FFs 2 Graafwater Sandstone Fynbos, but the high altitude communities share species with FFs 5 Winterhoek Sandstone Fynbos. The unit is rich in endemic species.

References Linder (1976), Moss & Mettlerkamp (1979).

FFs 7 North Hex Sandstone Fynbos

VT 69 Macchia (69%), VT 46 Coastal Renosterbosveld (24%) (Acocks 1953). Mesic Mountain Fynbos (82%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (81%) (Low & Rebelo 1996). BHU 52 Matroosberg Mountain Fynbos Complex (81%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Northern slopes of the Hex River Mountains from Mitchell's Pass near Ceres to Sonklip Ridge extending along the northern slope of the lower-altitude Witberg Ridge to Grootstraat west of Touws River. Altitude 500–1 800 m. (The highest ridges and peaks of the mountains support FFs 30 Western Altimontane Sandstone Fynbos.)

Vegetation & Landscape Features North-facing steep and gentle slopes from foothills to high mountain peaks. The dominant restiolands often have a proteoid overstorey. Asteraceous fynbos found on lower slopes.

Geology & Soils Acidic lithosol soils derived from Ordovician sandstones of the Table Mountain Group (Cape Supergroup). Land types mainly Ib and Ic.

Climate MAP 300–1 800 mm (mean: 750 mm), peaking markedly May to August. Snow regular in winter on higher slopes and may last for a week or more. Mean daily maximum and

L. Mucina

Figure 4.28 FFs 7 North Hex Sandstone Fynbos: Restioid fynbos on sandstone slopes under a fresh June snow cover in the Spekrivierkloof Valley, Matroosberg Private Reserve, Hex River Mountains (Western Cape).

minimum temperatures 26.0°C and 2.5°C for February and July, respectively. Frost incidence 10–50 days per year. See also climate diagram for FFs 7 North Hex Sandstone Fynbos (Figure 4.21).

Important Taxa Tall Shrubs: *Protea laurifolia* (d), *P. repens* (d), *Leucadendron rubrum*, *Metalasia muraltiifolia*, *Protea magnifica*. Low Shrubs: *Stoebe plumosa* (d), *Aspalathus crenata*, *A. rugosa*, *A. rupestris*, *Athanasia elsiae*, *Dolichothrix ericoides*, *Euryops othonnoides*, *Leucadendron arcuatum*, *L. salignum*, *Metalasia phillipsii* subsp. *incurva*, *M. rogersii*, *Paranomus candicans*, *Phylica chionocephala*, *Prismatocarpus brevilobus*, *Protea amplexicaulis*, *P. effusa*, *P. pityphylla*, *P. witzenbergiana*, *Ursinia pinnata, Zyrphelis pilosella*. Herbs: *Edmondia fasciculata*, *Ursinia sericea*. Geophytic Herb: *Ornithogalum esterhuyseniae*. Graminoids: *Askidiosperma capitatum*, *Calopsis marlothii*, *Elegia filacea*, *Ficinia gydomontana*, *Ischyrolepis laniger*, *Pentaschistis ampla*, *P. colorata*, *P. rosea* subsp. *purpurascens*.

D. Gwynne-Evans

Figure 4.29 FFs 8 South Hex Sandstone Fynbos: Restioid fynbos on ridge below Waaihoek Mountain in the Hex River Mountains (Western Cape).

Endemic Taxa Low Shrubs: *Erica atrovinosa*, *E. cereris*, *Lachnaea funicaulis*.

Conservation Least threatened. Target 29%. Statutorily conserved (34%) in the Ben Etive, Bokkeriviere and Ceres Mountain Fynbos Nature Reserves, with an additional 46% conserved in the Matroosberg Private Nature Reserve. Only 6% transformed (cultivation), mostly along the low-altitude edge of the unit. *Pinus radiata* is an occasional alien. Erosion is very low.

Remarks The Hex River Mountains are still botanically poorly researched: our knowledge of vegetation patterns is insufficient as most of the area is very difficult to access. The largest blocks of FFs 30 Western Altimontane Sandstone Fynbos are embedded within this unit.

Reference L. Mucina & E. Pienaar (unpublished data).

FFs 8 South Hex Sandstone Fynbos

VT 69 Macchia (96%) (Acocks 1953). Mesic Mountain Fynbos (98%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (97%) (Low & Rebelo 1996). BHU 52 Matroosberg Mountain Fynbos Complex (91%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Southern slopes of the Hex River Mountains from Mosterthoek Twins southeast of Wolseley to Kleinstraat west of Touws River. Altitude 400–1 800 m. (The highest ridges and peaks of the mountains support FFs 30 Western Altimontane Sandstone Fynbos.)

Vegetation & Landscape Features Rugged mountainous terrain with steep, high cliffs and steep slopes facing south and deeply dissected down to valley floors, creating some of the most dramatic relief in the country, for example at Baboon Peak. Vegetation is restioid shrubland with proteoid overstorey. Structurally it is mainly proteoid and restioid fynbos, also with some asteraceous fynbos. Ericaceous fynbos becomes prominent at higher altitudes.

Geology & Soils Acidic lithosol soils derived from Ordovician sandstones of the Table Mountain Group (Cape Supergroup). Land types mainly Ic.

Climate MAP 300–2 300 mm (mean: 955 mm), peaking markedly May to August. Snow regular in winter. Southeasterly cloud may bring heavy mist precipitation at higher altitudes in summer. This is the third wettest type of the Cape vegetation. Mean daily maximum and minimum monthly temperatures 26.0°C and 2.7°C for February and July, respectively. Frost incidence 10–30 days per year. See also climate diagram for FFs 8 South Hex Sandstone Fynbos (Figure 4.21).

Important Taxa ([T]Cape thickets) Small Trees: *Brabejum stellatifolium*[T], *Protea nitida*. Tall Shrubs: *Dodonaea viscosa* var. *angustifolia* (d), *Protea laurifolia* (d), *Leucadendron rubrum*, *Protea repens*. Low Shrubs: *Cliffortia ruscifolia* (d), *Oedera sedifolia* (d), *Stoebe cinerea* (d), *Amphithalea spinosa*, *Aspalathus bracteata*, *A. nigra*, *A. pachyloba* subsp. *villicaulis*, *A. radiata* subsp. *radiata*, *A. rugosa*, *Erica cymosa* subsp. *grandiflora*, *Leucadendron salignum*, *L. tinctum*, *Protea effusa*, *Serruria dodii*. Herb: *Ursinia sericea*. Geophytic Herbs: *Geissorhiza rupicola*, *G. scopulosa*. Graminoid: *Elegia stokoei*.

Endemic Taxa Tall Shrub: *Xiphotheca cordifolia*. Low Shrubs: *Agathosma concava*, *Anaxeton angustifolium*, *Aspalathus pachyloba* subsp. *rugulicarpa*, *A. pilantha*, *Athanasia alba*, *Disparago barbata*, *Erica coacervata*, *E. erasmia*, *E. hexensis*, *E. navigatoris*, *E. rimarum*, *E. salicina*, *E. tarantulae*, *Heliophila filicaulis*, *Leucospermum tottum* var. *glabrum, Muraltia serrata*, *Phylica chionophila*, *P. reversa*, *P. subulifolia*, *Phyllosma barosmoides*, *Prismatocarpus tenellus*, *Selago michelliae*, *Thamnea thesioides*, *Ursinia merxmuelleri*. Succulent Shrubs: *Delosperma burtoniae*, *Esterhuysenia inclaudens*, *Lampranthus brevistamineus*. Semiparasitic Shrubs: *Thesium annulatum*, *T. microcephalum*. Herbs: *Chamarea esterhuyseniae*, *Pseudoselago prolixa*. Geophytic Herb: *Moraea nubigena*. Graminoid: *Ischyrolepis fuscidula*.

Conservation Least threatened. Target 29%. Statutorily conserved (16%) in the Fonteintjiesberg Nature Reserve, with an additional about 10% in Matroosberg Private Nature Reserve. Only very small portion transformed and alien woody plants are rare (*Pinus radiata*). Erosion very low.

Remarks This vegetation unit has the largest area of Western Altimontane Sandstone Fynbos (FFs 30) embedded in it. Altitudinal zonation is clearly evident here, as in a number of other 'mountain fynbos' units but remains undocumented. For example, *Protea punctata* stands out as a typical tall shrub

near the upper limits of this unit (i.e. immediately below FFs 30 Western Altimontane Sandstone Fynbos).

Reference Chesselet (1985).

FFs 9 Peninsula Sandstone Fynbos

VT 69 Macchia (90%) (Acocks 1953). Mesic Mountain Fynbos (91%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (93%) (Low & Rebelo 1996). BHU 55 Cape Peninsula Mountain Fynbos Complex (100%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Confined to the Cape Peninsula, from the top of Lion's Head and Table Mountain (Cape Town) to Cape Point and Cape of Good Hope and including Constantiaberg and Swartkopsberge. Altitude range 20–1 086 m at Maclear's Beacon on Table Mountain.

Vegetation & Landscape Features Gentle to steep slopes, with cliffs in the north, over a 50 km long peninsula. Vegetation is a medium dense, tall proteoid shrubland over a dense moderately tall, ericoid-leaved shrubland—mainly proteoid, ericaceous and restioid fynbos, with some asteraceous fynbos.

Geology & Soils Acidic lithosol soils derived from Ordovician sandstones of the Table Mountain Group (Cape Supergroup), Lamotte forms prominent. Land types mainly Ib, Ga and Ic.

Climate MAP 520–1 690 mm (mean: 780 mm), peaking May to August. Mean daily maximum and minimum temperatures 25.0°C and 7.2°C for February and July, respectively. Frost incidence 2 or 3 days per year. Southeasterly cloud (the famous 'Table Cloth'), accompanied by high wind, brings heavy mist precipitation at higher altitudes to southern and eastern slopes in summer. The region is under strong maritime influence—no part is more than 7 km from the sea. See also climate diagram for FFs 9 Peninsula Sandstone Fynbos (Figure 4.21).

Important Taxa ([W]Wetlands) Small Tree: *Leucospermum conocarpodendron* subsp. *viridum*. Tall Shrubs: *Metalasia densa* (d), *Phylica buxifolia* (d), *Protea lepidocarpodendron* (d), *Psoralea aphylla* (d), *Aspalathus linearis*, *Erica tristis*, *Euryops abrotanifolius*. Low Shrubs: *Anthospermum galioides* subsp. *galioides* (d), *Berzelia lanuginosa*[W] (d), *Cliffortia drepanoides* (d), *C. ruscifolia* (d), *C. subsetacea* (d), *Cryptadenia grandiflora* (d), *Elytropappus gnaphaloides* (d), *Erica axillaris* (d), *E. ericoides* (d), *E. hispidula* (d), *E. imbricata* (d), *E. labialis* (d), *E. muscosa* (d), *Felicia fruticosa* subsp. *fruticosa* (d), *Helichrysum cymosum* (d), *Leucadendron laureolum* (d), *L. xanthoconus* (d), *Otholobium hirtum* (d), *Penaea mucronata* (d), *Roella ciliata* (d), *Saltera sarcocolla* (d), *Stoebe cinerea* (d), *S. fusca* (d), *Syncarpha speciosissima* (d), *S. vestita* (d), *Anthospermum aethiopicum*, *Aspalathus argyrella*, *A. aspalathoides*, *A. callosa*, *A. commutata*, *A. cordata*, *A. crenata*, *A. filicaulis*, *A. macrantha*, *A. psoraleoides*, *A. quinquefolia* subsp. *compacta*, *A. retroflexa* subsp. *retroflexa*, *A. tridentata* subsp. *tridentata*, *Capelio tabularis*, *Clutia polygonoides*, *Cullumia ciliaris*, *Erica benthamiana*, *E. corifolia*, *E. exleeana*, *E. hirtiflora*, *E. lutea*, *E. multumbellifera*, *E. parviflora*[W], *E. plukenetii* subsp. *plukenetii*, *E. pulchella*, *E. sessiliflora*, *E. similis*, *E. viscaria* subsp. *viscaria*, *Euryops pectinatus* subsp. *pectinatus*, *Helichrysum pandurifolium*, *Metalasia brevifolia*, *Muraltia pageae*, *Osmitopsis asteriscoides*[W], *Otholobium fruticans*, *Passerina truncata* subsp. *monticola*, *Pelargonium cucullatum*, *Phylica imberbis*, *Protea cynaroides*, *Struthiola ciliata* subsp. *angustifolia*, *Stylapterus fruticulosus*, *Ursinia paleacea*, *Witsenia maura*[W], *Zyrphelis foliosa*, *Z. taxifolia*. Semiparasitic Shrub: *Thesium virgatum* (d). Herbs: *Corymbium africanum*, *Indigofera psoraloides*, *Ursinia nudicaulis*. Geophytic Herbs: *Aristea bakeri*, *Geissorhiza aspera*, *G. bolusii*[W], *G. hispidula*, *G. imbricata* subsp. *imbricata*[W], *G. juncea*, *G. ovata*, *G. similis*, *G. tenella*, *G. umbrosa*, *Trachyandra hirsutiflora*. Graminoids: *Anthochortus crinalis* (d), *Ehrharta ramosa* subsp. *aphylla* (d), *Elegia ebracteata* (d), *E. hookeriana* (d), *E. mucronata* (d), *E. neesii* (d), *E. racemosa* (d), *E. stipularis* (d), *E. thyrsifera* (d), *E. vaginulata* (d), *Ficinia acuminata* (d), *F. bulbosa* (d), *F. nigrescens* (d), *F. oligantha* (d), *F. trichodes* (d), *Hypodiscus aristatus* (d), *Ischyrolepis cincinnata* (d), *I. gaudichaudiana* (d), *Pentameris macrocalycina* (d), *Platycaulos compressus* (d), *Pseudopentameris macrantha* (d), *Restio bifidus* (d), *R. perplexus* (d), *Staberoha distachyos* (d), *S. vaginata* (d), *Tetraria flexuosa* (d), *T. involucrata* (d), *Thamnochortus fruticosus* (d), *T. lucens* (d), *T. obtusus* (d), *Ehrharta villosa* var. *villosa*, *Ischyrolepis capensis*, *Pentaschistis colorata*, *Restio dodii*[W], *Tetraria cuspidata*, *T. ligulata*, *T. microstachys*.

Endemic Taxa ([W]Wetlands) Small Tree: *Mimetes fimbriifolius*. Tall Shrubs: *Erica caterviflora*, *Leucadendron macowanii*, *L. strobilinum*, *Liparia laevigata*. Low Shrubs: *Diastella divaricata* subsp. *divaricata* (d), *Agathosma lanceolata*, *A. pulchella*, *Anaxeton arborescens*, *Aspalathus barbata*, *A. borboniifolia*, *A. capensis*, *A. capitata*, *A. chenopoda* subsp. *chenopoda*, *A. incurva*, *Brachysiphon fucatus*, *Cliffortia discolor*, *Cyclopia galioides*, *C. latifolia*, *Erica abietina* subsp. *abietina*, *E. abietina* subsp. *atrorosea*, *E. abietina* subsp. *constantiana*, *E. abietina* subsp. *diabolis*, *E. amoena*[W], *E. annectens*, *E. capensis*[W], *E. clavisepala*[W], *E. cyrilliflora*[W], *E. depressa*, *E. diosmifolia*, *E. eburnea*, *E. empetrina*, *E. fairii*, *E. fontana*[W], *E. haematocodon*, *E. halicacaba*, *E. heleogena*[W], *E. limosa*[W], *E. marifolia*, *E. mollis*[W], *E. nevillei*, *E. oxycoccifolia*, *E. paludicola*[W], *E. physodes*, *E. pilulifera*[W], *E. planifolia*, *E. pyxidiflora*, *E. quadrisulcata*, *E. salteri*[W], *E. sociorum*, *E. subcapitata*, *E. urna-viridis*, *Indigofera candolleana*, *I. filiformis*, *I. mauritanica*, *Lebeckia macowanii*, *Liparia parva*, *Metalasia compacta*, *M. divergens* subsp. *divergens*, *M. divergens* subsp. *fusca*, *Microdon nitidus*, *Morella diversifolia*, *Muraltia acipetala*, *M. brachypetala*,

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Figure 4.30 FFs 9 Peninsula Sandstone Fynbos: Proteoid fynbos with prominent ericaceous and restioid elements at Cape Point in the Table Mountain National Park (Western Cape). The broad recurved leaves belong to *Tetraria thermalis* (Cyperaceae).

M. comptonii, *M. curvipetala*, *M. demissa*, *M. diabolica*, *M. mixta*, *M. orbicularis*, *Osmitopsis dentata*, *Phylica schlechteri*, *Prismatocarpus nitidus*, *Roella amplexicaulis*, *R. decurrens*, *R. goodiana*, *R. recurvata*, *R. squarrosa*, *R. triflora*, *Serruria collina*, *S. cyanoides*, *S. decumbens*, *S. hirsuta*, *S. villosa*, *Staavia dodii*, *S. glutinosa*, *Stoebe rosea*, *Wahlenbergia pyrophila*[W]. Succulent Shrubs: *Aloe commixta*, *Erepsia forficata*, *Lampranthus austricola*, *L. incurvus*, *L. multiradiatus*, *L. promontorii*, *L. roseus*, *L. tenuis*. Semiparasitic Shrub: *Thesium pseudovirgatum*. Herbs: *Gerbera wrightii*, *Helichrysum fruticans*, *H. grandiflorum*, *Heliophila promontorii*, *H. tabularis*, *Lobelia eckloniana*[W], *Nemesia micrantha*, *Pseudoselago peninsulae*, *Scabiosa africana*, *Senecio verbascifolius*, *Ursinia tenuifolia* subsp. *tenuifolia*, *Villarsia goldblattiana*[W]. Geophytic Herbs: *Bobartia gladiata* subsp. *major*[W], *Disa nubigena*, *Geissorhiza bonaspei*, *G. tabularis*[W], *Gethyllis kaapensis*, *Gladiolus aureus*[W], *G. bonaspei*, *G. monticola*, *G. vigilans*, *Lachenalia capensis*, *Pterygodium connivens*, *Watsonia tabularis*[W], *Wurmbea hiemalis*. Carnivorous Herb: *Drosera cuneifolia*[W]. Graminoids: *Thamnochortus nutans* (d), *Anthochortus capensis*, *Calopsis gracilis*, *Elegia intermedia*[W], *Eleocharis lepta*[W], *Ficinia anceps*, *F. fastigiata*, *F. micrantha*, *Isolepis bulbifera*, *I. pusilla*, *Restio communis*, *Tetraria graminifolia*, *T. paludosa*, *Thamnochortus levynsiae*.

Conservation Least threatened. Target 30%. Statutorily well conserved (90%) in the Table Mountain National Park. About 75% transformed (urban sprawl, pine plantations). *Acacia melanoxylon* and *Pinus pinaster* are occasional woody aliens. Many local patches of alien vegetation are very dense. Erosion very low.

Remarks This unit is, not surprisingly, the best explored and described vegetation type in the biome due to its locality in the Cape Town metropolitan area and near the University of Cape Town as a major research institution. A finer-scale mapping of the structural-floristic types can be found in Taylor (1984b) and Simmons (1996).

References Adamson (1927), Adamson & Salter (1950), Taylor (1969, 1981, 1983, 1984a, b), Cowling (1976), McKenzie (1976), McKenzie et al. (1977), Glyphis et al. (1978), Laidler et al. (1978), Kathan (1981), Jeffery & Wilson (1987), Barnes (1992), Greenfield (1992), Irwing (1992), Kirkwood (1992), Rule (1992), Simmons (1992, 1996), Cowling et al. (1996b), Privett (1998), Boucher (1999a).

FFs 10 Hawequas Sandstone Fynbos

VT 69 Macchia (95%) (Acocks 1953). Mesic Mountain Fynbos (94%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (94%) (Low & Rebelo 1996). BHU 53 Hawequas Mountain Fynbos Complex (92%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Between the Nuwekloof Pass near Gouda in the north to Franschhoek Pass near Franschhoek including the Elandskloof, Hawequas, Slanghoek, Klein-Drakenstein, Wemmershoek, Du Toitskloof and Stettyns Mountains. Altitude 250–1 800 m. Patches of FFs 30 Western Altimontane Sandstone Fynbos on some of the few peaks above 1 800 m.

Vegetation & Landscape Features Mountains with slopes of various steepness, flanks of intermontane valleys and upland plateaus. A band of Cedarberg Shale Formation forms a prominent step at high altitude. Vegetation a low closed shrubland dotted with emergent tall shrubs—mainly proteoid, restioid and asteraceous fynbos with much waboomveld at lower altitudes, ericaceous fynbos at higher altitudes and abundant Cape thickets (especially in the north of the unit) on cliffs and very steep rocky (scree) slopes.

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Figure 4.31 FFs 10 Hawequas Sandstone Fynbos: *Hymenolepis parviflora* (Asteraceae) on the rocky slopes of the Bain's Kloof near Wellington (Western Cape) covered by dense fynbos shrublands with seeps (green-yellow patches in the background) dominated by *Leucadendron salicifolium*.

Geology & Soils Acidic lithosol soils derived from Ordovician sandstones of the Table Mountain Group (Cape Supergroup). Land types mainly Ic and Ib.

Climate MAP 530–2 140 mm (mean: 1 200 mm), peaking markedly May to August. Mean daily maximum and minimum temperatures 25.4°C and 4.4°C for February and July, respectively. Frost incidence 3–20 days per year. Southeasterly cloud brings heavy mist precipitation to southern and eastern slopes at higher altitudes in summer. See also climate diagram for FFs 10 Hawequas Sandstone Fynbos (Figure 4.21).

Important Taxa ([T]Cape thickets, [W]Wetlands) Small Trees: *Brabejum stellatifolium*[T] (d), *Heeria argentea*[T] (d), *Metrosideros angustifolia*[T] (d), *Protea nitida* (d), *Widdringtonia nodiflora* (d). Succulent Tree: *Aloe plicatilis*. Tall Shrubs: *Cassine schinoides*[T] (d), *Leucadendron salicifolium* (d), *Maytenus acuminata*[T] (d), *Metalasia densa* (d), *Morella serrata* (d), *Myrsine africana*[T] (d), *Olea europaea* subsp. *africana*[T] (d), *Protea laurifolia* (d), *P. repens* (d), *Psoralea pinnata*[W] (d), *Aspalathus linearis*, *Diospyros glabra*[T], *Euryops abrotanifolius*, *Liparia rafnioides*, *Metalasia muraltiifolia*, *Rhus lucida*[T], *R. tomentosa*[T], *R. undulata*[T]. Low Shrubs: *Berzelia lanuginosa*[W] (d), *Brunia nodiflora* (d), *Cliffortia dregeana*[W] (d), *C. graminea* (d), *C. ruscifolia* (d), *Erica hispidula* (d), *E. nudiflora* (d), *E. plukenetii* subsp. *plukenetii* (d), *E. totta* (d), *Leucadendron salignum* (d), *Maytenus oleoides*[T] (d), *Osmitopsis asteriscoides*[W] (d), *Penaea mucronata* (d), *Stoebe cinerea* (d), *S. plumosa* (d), *Anthospermum aethiopicum*, *A. prostratum*, *Aspalathus attenuata*, *A. bracteata*, *A. ciliaris*, *A. commutata*, *A. cordata*, *A. crenata*, *A. cytisoides*, *A. divaricata* subsp. *gra-*

cilior, *A. filicaulis*, *A. lanceifolia*, *A. pachyloba* subsp. *pachyloba*, *A. perfoliata* subsp. *perfoliata*, *A. perforata*, *A. pinea* subsp. *caudata*, *A. quinquefolia* subsp. *compacta*, *A. radiata* subsp. *radiata*, *A. rugosa*, *A. ulicina* subsp. *ulicina*, *Clutia alaternoides*, *Diosma hirsuta*, *Elytropappus glandulosus*, *Erica benthamiana*, *E. daphniflora*, *E. parilis*, *E. phillipsii*, *E. rigidula*, *E. ventricosa*, *Euryops pectinatus* subsp. *pectinatus*, *E. rupestris* var. *dasycarpus*, *E. rupestris* var. *rupestris*, *Gnidia anomala*, *G. oppositifolia*, *Leucadendron spissifolium* subsp. *spissifolium*, *Leucospermum tottum*, *Linconia cuspidata*, *Lobelia coronopifolia*, *Metalasia cephalotes*, *M. dregeana*, *M. fastigiata*, *M. rhoderoides*, *Paranomus capitatus*, *Passerina truncata* subsp. *monticola*, *Pelargonium cucullatum*, *P. tabulare*, *Printzia aromatica*, *Protea acaulos*, *P. effusa*, *P. nana*, *Psoralea lucida*, *Rhus scytophylla*[T], *Stoebe incana*, *Thamnea uniflora*, *Ursinia filipes*[W], *U. paleacea*, *U. pinnata*, *U. punctata*. Succulent Shrubs: *Oscularia deltoides* (d), *Crassula coccinea*. Woody Climber: *Secamone alpini*[T] (d). Herbs: *Knowltonia capensis*[T] (d), *Corymbium scabrum*, *Dianthus bolusii*, *Grammatotheca bergiana*[W], *Ursinia oreogena*. Geophytic Herbs: *Lanaria lanata* (d), *Mohria caffrorum* (d), *Aristea africana*, *A. capitata*, *Geissorhiza alticola*, *G. aspera*, *G. bolusii*[W], *G. confusa*, *G. grandiflora*, *G. ovalifolia*, *G. ovata*, *G. pseudinaequalis*, *G. ramosa*, *G. scillaris*, *Romulea flexuosa*. Graminoids: *Anthochortus graminifolius* (d), *Askidiosperma paniculatum* (d), *Cannomois parviflora* (d), *Chrysitrix capensis* (d), *Cymbopogon marginatus* (d), *Ehrharta dura* (d), *E. ramosa* subsp. *aphylla* (d), *Elegia capensis*[W] (d), *E. neesii* (d), *E. thyrsifera* (d), *E. vaginulata* (d), *Hypodiscus argenteus* (d), *H. aristatus* (d), *Ischyrolepis curviramis* (d), *I. gaudichaudiana* (d), *Neesenbeckia punctoria* (d), *Pentaschistis eriostoma* (d), *Restio pedicellatus* (d), *R. perplexus* (d), *Staberoha cernua* (d), *Tetraria crinifolia* (d), *T. cuspidata* (d), *T. fasciata* (d), *T. ustulata* (d), *Cannomois virgata*, *Elegia asperiflora*, *Ficinia distans*, *F. oligantha*, *Ischyrolepis capensis*, *I. sieberi*, *Merxmuellera rufa*, *Pentaschistis curvifolia*, *Restio filiformis*, *Tetraria involucrata*, *Thamnochortus fruticosus*, *Willdenowia sulcata*.

Endemic Taxa ([W]Wetlands) Low Shrubs: *Acmadenia faucitincta*, *Agathosma decurrens*, *A. lancifolia*, *A. rudolphii*, *Amphithalea bodkinii*[W], *A. concava*, *Aspalathus caespitosa*, *A. erythrodes*, *A. linearifolia*, *A. radiata* subsp. *pseudosericea*, *A. secunda* (limited to Riebeek-Kasteel Mt), *A. truncata*, *Cliffortia lanata*, *C. pilifera*, *C. rigida*, *C. strigosa*, *C. subdura*, *Cyclopia squamosa*, *Diastella myrtifolia*, *Erica blandfordia*, *E. chionophila*[W], *E. chrysocodon*[W], *E. cremea*[W], *E. cylindrica*, *E. cymosa* subsp. *cymosa*, *E. feminarum*[W], *E. hibbertii*, *E. intricata*[W], *E. limnophila*[W], *E. praecox*, *E. purgatoriensis*[W], *E. rehmii*[W], *E. schumannii*, *E. walkeria*, *E. wittebergensis*, *Euryops decipiens*, *Euthystachys abbreviata*, *Gnidia insignis*, *Hydroidea elsiae*, *Lachnaea pusilla*, *Metalasia montana*, *Muraltia alba*, *Nivenia corymbosa*, *Osmitopsis tenuis*, *Phylica ampliata*, *P. comosa*, *P. nodosa*, *Polyarrhena prostrata*, *Psoralea oreophila*, *Rafnia capensis* subsp. *elsieae*, *Salvia thermaruma*, *Serruria rosea*, *S. triternata*, *Sorocephalus teretifolius*, *Spatalla salsoloides*, *Stylapterus ericoides* subsp. *ericoides*, *S. ericoides* subsp. *pallidus*, *S. sulcatus*, *Ursinia abrotanifolia*, *Zyrphelis decumbens*, *Z. montana*. Succulent Shrubs: *Erepsia insignis*, *Lampranthus acutifolius*, *L. capillaceus*, *L. villiersii*. Semiparasitic Shrub: *Thesium diversifolium*. Herbs: *Arctotis macrosperma*, *A. rotundifolia*, *Centella restioides*, *Nemesia picta*. Geophytic Herbs: *Gladiolus phoenix*, *G. rhodanthus*, *Ixia metelerkampiae*, *Oxalis pseudo-hirta*, *Pelargonium nummulifolium*, *Spetaea lachenaliiflora*[W], *Thereianthus ixioides*, *Tritoniopsis pulchella*. Carnivorous Herb: *Drosera regia*[W]. Graminoids: *Ischyrolepis coactilis*, *Restio alticola*, *R. inveteratus*, *R. montanus*, *R. singularis*.

Conservation Least threatened. Target 30%. More than half statutorily conserved in the Limietberg, Theewaters and Waterval Nature Reserves, with an additional 36% protected in the Hawequas Mountain Catchment Area. Only 4% transformed (pine plantations, cultivation). Local occurrences of alien *Hakea sericea* and *Pinus pinaster* are of concern. Erosion very low.

Remarks Like the neighbouring (to the south) FFs 11 Kogelberg Sandstone Fynbos, this unit has high specific endemism. Endemic genera include *Spetaea* (Hyacinthaceae) and *Hydroidea* (Asteraceae). *Empleuridium* and *Euthystachys* are Cape endemic genera shared only with FFs 11 Kogelberg Sandstone Fynbos.

References Kruger (1974, 1979), Parkman (1978), Van Wilgen & Kruger (1981, 1985), Boucher (1988b, 1994a, 1996b), L. Mucina (unpublished data).

FFs 11 Kogelberg Sandstone Fynbos

VT 69 Macchia (98%) (Acocks 1953). Mesic Mountain Fynbos (81%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (93%) (Low & Rebelo 1996). BHU 56 Kogelberg Mountain Fynbos Complex (63%), BHU 54 Franschhoek Mountain Fynbos Complex (32%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: From Franschhoek, Groot-Drakensteinberge and Simonsberg (near Stellenbosch) in the north passing southwards between Gordon's Bay and Bot River to Cape Hangklip and Kleinmond in the south including the Jonkershoek, Stellenbosch, Franschhoek, Groenland, Hottentots Holland, Kogelberg and Palmietberge Mountains. Altitude 20–1 590 m at summit of Somerset Sneeukop.

Vegetation & Landscape Features High mountains with steep to gentle slopes, and undulating plains and hills of varied aspect. General appearance of vegetation low, closed shrub-

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Figure 4.32 FFs 11 Kogelberg Sandstone Fynbos: Proteoid fynbos (with local endemic *Leucospermum bolusii*) on sandstone colluvium on a sea-facing slope of the Kogelberg massif (near Steenbras River mouth in False Bay, Western Cape).

land with scattered emergent tall shrubs. Proteoid, ericaceous and restioid fynbos dominate, while asteraceous fynbos is rare. Patches of Cape thicket are common in the northern areas; in the south similar habitats are occupied by scrub fynbos. Numerous seeps and seasonally saturated mountain-plateau wetlands (locally called 'suurvlakte') are very common and support restioid and ericaceous (dominated by Bruniaceae) fynbos.

Geology & Soils Acidic lithosol soils derived from Ordovician sandstones of the Table Mountain Group (Cape Supergroup). Deep sandy blankets (whitish, nutrient-poor acidic sand) develop in depressions and on slopes resisting erosion. Land types mainly Ic, Ib and Gb.

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Figure 4.33 FFs 11 Kogelberg Sandstone Fynbos: Species-rich proteoid fynbos on coastal sandy plains in the Kleinmond Nature Reserve at the Palmiet River mouth near Kleinmond (Western Cape), with small trees of *Leucospermum conocarpodendron* subsp. *viridum* and pink-flowered *Pelargonium cucullatum* (Geraniaceae).

Climate MAP 670–3 000 mm (mean: 1 330 mm), peaking markedly May to August. This region has the highest recorded rainfall in the Cape (see Section 2.4.2 of this chapter). Mean daily maximum and minimum temperatures 24.0°C and 6.1°C for February and July, respectively. Frost incidence 2 or 3 days per year. The summit cloud (the 'Hottentot's Blanket') is a regular feature in summer when the Southeaster (part of the global system of trade-winds) brings heavy mist precipitation to the summits and adjacent south-facing and east-facing slopes. See also climate diagram for FFs 11 Kogelberg Sandstone Fynbos (Figure 4.21).

Important Taxa ([T]Cape thickets, [W]Wetlands) Small Trees: *Brabejum stellatifolium*[T] (d), *Widdringtonia nodiflora* (d), *Heeria argentea*[T], *Leucospermum conocarpodendron* subsp. *viridum*, *Metrosideros angustifolia*[T], *Podocarpus elongatus*[T], *Protea nitida*. Tall Shrubs: *Brunia albiflora*[W] (d), *Cliffortia cuneata* (d), *Diospyros glabra*[T] (d), *Leucadendron salicifolium* (d), *Liparia myrtifolia* (d), *Metalasia densa* (d), *Mimetes argenteus* (d), *Protea neriifolia* (d), *P. repens* (d), *Psoralea pinnata*[W] (d), *Aspalathus linearis*, *A. willdenowiana*, *Cunonia capensis*[T], *Erica perspicua* var. *perspicua*[W], *Euryops abrotanifolius*, *E. serra*, *Laurophyllus capensis*[T], *Liparia rafnioides*, *Myrsine africana*[T], *Pseudobaeckea africana*, *Psoralea aphylla*, *Rapanea melanophloeos*[T], *Rhus tomentosa*[T]. Low Shrubs: *Agathosma ovata* (d), *A. serratifolia* (d), *Aulax cancellata* (d), *Berzelia lanuginosa*[W] (d), *B. squarrosa* (d), *Brunia alopecuroides*[W] (d), *Cliffortia graminea* (d), *C. hirsuta* (d), *C. pedunculata* (d), *C. polygonifolia* (d), *C. ruscifolia* (d), *Cullumia setosa* (d), *Diosma hirsuta* (d), *Erica coccinea* subsp. *coccinea* (d), *E. desmantha* (d), *E. equisetifolia* (d), *E. fastigiata* (d), *E. hispidula* (d), *E. imbricata* (d), *E. labialis* (d), *E. lutea* (d), *E. muscosa* (d), *E. parviflora*[W] (d), *E. pulchella* (d), *E. similis* (d), *E. viscaria* subsp. *longifolia* (d), *Euryops pinnatipartitus* (d), *Grubbia tomentosa* (d), *Leucadendron gandogeri* (d), *L. platyspermum* (d), *L. salignum* (d), *L. spissifolium* subsp. *spissifolium* (d), *L. xanthoconus* (d), *Leucospermum oleifolium* (d), *Mimetes cucullatus* (d), *Nebelia fragarioides* (d), *N. paleacea* (d), *N. sphaerocephala* (d), *Osmitopsis asteriscoides*[W] (d), *Otholobium obliquum* (d), *Penaea mucronata* (d), *Phaenocoma prolifera* (d), *Phylica anomala* (d), *Protea cynaroides* (d), *P. grandiceps* (d), *Retzia capensis* (d), *Roella ciliata* (d), *Saltera sarcocolla* (d), *Serruria inconspicua* (d), *Stoebe incana* (d), *S. plumosa* (d), *Syncarpha vestita* (d), *Ursinia paleacea* (d), *Amphithalea ericifolia* subsp. *scoparia*, *Anaxeton asperum*, *Anthospermum aethiopicum*, *A. galioides* subsp. *galioides*, *Aspalathus angustifolia* subsp. *angustifolia*, *A. aspalathoides*, *A. attenuata*, *A. bracteata*, *A. caledonensis*, *A. callosa*, *A. ciliaris*, *A. commutata*, *A. cordata*, *A. crenata*, *A. cytisoides*, *A. divaricata* subsp. *divaricata*, *A. divaricata* subsp. *gracilior*, *A. dunsdoniana*, *A. filicaulis*, *A. intervallaris*, *A. macrantha*, *A. marginata*, *A. oblongifolia*, *A. perfoliata* subsp. *perfoliata*, *A. perforata*, *A. pinea* subsp. *caudata*, *A. radiata* subsp. *radiata*, *A. ramulosa*, *A. stenophylla*, *A. tridentata* subsp. *tridentata*, *Asparagus lignosus*, *A. rubicundus*, *Berzelia abrotanoides*, *B. intermedia*, *Brunia laevis*, *B. nodiflora*, *Capelio tabularis*, *Cliffortia atrata*, *C. exilifolia*, *Clutia polygonoides*, *Diastella divaricata* subsp. *montana*, *Dolichothrix ericoides*, *Elytropappus gnaphaloides*, *Erica axillaris*, *E. benthamiana*, *E. corifolia*, *E. corydalis*, *E. curviflora*, *E. ericoides*, *E. exleeana*, *E. intervallaris*[W], *E. massonii*, *E. odorata*, *E. petrophila*, *E. pilosiflora* subsp. *pilosiflora*, *E. plukenetii* subsp. *plukenetii*, *E. rigidula*, *E. serrata*, *E. sessiliflora*, *E. taxifolia*, *E. totta*, *E. transparens*, *E. ventricosa*, *Euryops rupestris* var. *dasycarpus*, *E. rupestris* var. *rupestris*, *Gnidia pinifolia*, *Halleria elliptica*, *Hermas villosa*, *Hippia pilosa*, *Indigofera glomerata*, *I. trita* subsp. *subulata*, *Klattia partita*, *Leucadendron laureolum*, *L. microcephalum*, *Linconia cuspidata*, *Liparia splendens*, *Lobelia pinifolia*, *Maytenus oleoides*[T], *Metalasia brevifolia*, *M. cephalotes*, *M. erubescens*, *M. inversa*, *M. plicata*, *M. tenuifolia*, *Microdon dubius*, *Osteospermum ciliatum*, *Otholobium fruticans*, *Paranomus sceptrum-gustavianus*, *Passerina truncata* subsp. *monticola*, *Phylica lasiocarpa*, *Polygala pottebergensis*, *Prismatocarpus diffusus*, *P. schlechteri*, *Protea angustata*, *P. lorea*, *P. scabra*, *P. speciosa*, *Raspalia microphylla*, *Roella incurva*, *Serruria acrocarpa*, *S. flagellifolia*, *S. phylicoides*, *S. rostellaris*, *S. rubricaulis*, *Spatalla longifolia*, *S. propinqua*[W], *S. racemosa*, *Teedia lucida*, *Thamnea uniflora*, *Ursinia pinnata*, *U. quinquepartita*[W], *Zyrphelis foliosa*, *Z. lasiocarpa*, *Z. taxifolia*. Succulent Shrubs: *Othonna quinquedentata* (d), *Crassula coccinea*, *Oscularia deltoides*. Semiparasitic Shrubs: *Thesium carinatum*, *T. ericaefolium*. Pseudocarnivorous Shrub: *Roridula gorgonias*. Herbs: *Arctotis semipapposa* (d), *Carpacoce spermacocea*, *Centella difformis*, *C. eriantha*, *C. virgata*, *Chironia decumbens*, *Corymbium congestum*, *C. glabrum*, *Edmondia sesamoides*, *Helichrysum litorale*, *Nemesia acuminata*, *Pseudoselago serrata*, *Ursinia nudicaulis*, *U. oreogena*, *Villarsia capensis*[W]. Geophytic Herbs: *Blechnum punctulatum* (d), *Lanaria lanata* (d), *Pteridium aquilinum* (d), *Schizaea pectinata* (d), *Watsonia borbonica* subsp. *borbonica* (d), *Agapanthus africanus*, *Aristea africana*, *A. capitata*, *Blechnum capense*, *Bobartia indica*, *Bulbinella nutans*

subsp. *turfosicola*[W], *Disa pillansii*[W], *Eriospermum bakerianum* subsp. *bakerianum*, *Geissorhiza aspera*, *G. burchellii*, *G. cataractarum*[W], *G. hesperanthoides*, *G. hispidula*, *G. intermedia*, *G. nubigena*, *G. ovata*, *G. parva*, *G. ramosa*, *G. schinzii*, *G. similis*, *G. umbrosa*, *Romulea flava*, *R. gracillima*, *R. schlechteri*[W], *Rumohra adiantiformis*, *Trachyandra tabularis*, *Wachendorfia thyrsiflora*[W]. Succulent Herb: *Crassula pellucida* subsp. *pellucida*. Carnivorous Herb: *Drosera glabripes*[W]. Graminoids: *Anthochortus crinalis* (d), *A. graminifolius* (d), *Askidiosperma paniculatum* (d), *Calopsis paniculata* (d), *Cannomois parviflora* (d), *C. virgata* (d), *Ceratocaryum argenteum* (d), *Cymbopogon marginatus* (d), *Elegia capensis*[W] (d), *E. deusta* (d), *E. ebracteata* (d), *E. filacea* (d), *E. grandis*[W] (d), *E. hookeriana* (d), *E. juncea* (d), *E. racemosa* (d), *E. spathacea* (d), *E. mucronata* (d), *E. thyrsifera* (d), *Hypodiscus albo-aristatus* (d), *H. aristatus* (d), *Ischyrolepis capensis* (d), *I. sieberi* (d), *I. tenuissima* (d), *Mastersiella digitata* (d), *Merxmuellera stricta* (d), *Nevillea obtusissima* (d), *Pentameris macrocalycina* (d), *Pentaschistis colorata* (d), *Restio bifidus* (d), *R. egregius* (d), *R. filiformis* (d), *R. perplexus* (d), *R. purpurascens* (d), *R. similis* (d), *Staberoha aemula* (d), *S. cernua* (d), *Tetraria bromoides* (d), *T. capillacea* (d), *T. compar* (d), *T. fasciata* (d), *T. flexuosa* (d), *T. involucrata* (d), *T. thermalis* (d), *Thamnochortus gracilis* (d), *T. pulcher* (d), *Willdenowia glomerata* (d), *Calopsis hyalina*, *C. membranacea*, *Carpha glomerata*, *Chrysitrix capensis*, *Cyathocoma hexandra*[W], *Ehrharta ramosa* subsp. *aphylla*, *Elegia stokoei*, *Epischoenus quadrangularis*, *Ficinia acuminata*, *F. albicans*, *F. ecklonea*, *F. trichodes*, *Hypodiscus willdenowia*, *Ischyrolepis gaudichaudiana*, *I. subverticillata*[W], *Neesenbeckia punctoria*, *Pentaschistis curvifolia*, *Platycaulos cascadensis*[W], *Restio ambiguus*, *R. dispar*, *R. occultus*, *R. triticeus*, *R. versatilis*, *Tetraria burmannii*, *T. ligulata*, *Willdenowia humilis*, *W. sulcata*.

Endemic Taxa ([W]Wetlands) Small Tree: *Mimetes arboreus*. Tall Shrubs: *Protea stokoei* (d), *Aspalathus globosa*, *A. stokoei*, *Cliffortia heterophylla*, *Liparia calycina*, *Mimetes hottentoticus*, *Orothamnus zeyheri*[W] (small population also in FFs 12), *Podalyria cordata*. Low Shrubs: *Berzelia dregeana* (d), *Erica cristata* (d), *E. sitiens* (d), *Leucospermum bolusii* (d), *Spatalla setacea*[W] (d), *Ursinia caledonica*[W] (d), *Acmadenia candida*, *A. nivea*, *Adenandra multiflora*, *Agathosma rosmarinifolia*, *A. stokoei*, *Amphithalea bowiei*, *A. oppositifolia*, *A. stokoei*, *Anaxeton ellipticum*, *Aspalathus acanthiloba*, *A. concava*, *A. monosperma*, *A. salicifolia*, *A. vacciniifolia*, *Berzelia ecklonii*, *Brunia stokoei*, *Capelio caledonica*, *Cliffortia hermaphroditica*, *C. ovalis*, *C. viridis*, *Diastella fraterna*, *D. thymelaeoides* subsp. *meridiana*, *D. thymelaeoides* subsp. *thymelaeoides*, *Erica amphigena*, *E. atricha*, *E. banksii* subsp. *banksii*, *E. banksii* subsp. *comptonii*, *E. bibax*[W], *E. cabernetea*, *E. campanularis*[W], *E. ceraria*, *E. chiroptera*, *E. cincta*, *E. cunoniensis*, *E. cygnea*, *E. extrusa*, *E. foliacea*, *E. gysbertii*, *E. hameriana*, *E. hottentotica*[W], *E. humidicola*[W], *E. intonsa*, *E. jacksoniana*[W], *E. kogelbergensis*, *E. krugeri*, *E. lananthera*, *E. latiflora*, *E. leucotrachela*, *E. lycopodiastrum*, *E. macroloma*, *E. magistrati*, *E. multiflexuosa*, *E. nana*, *E. notholeeana*, *E. oreophila*, *E. pageana*[W], *E. perplexa*, *E. pillansii* subsp. *fervida*[W], *E. pillansii* subsp. *pillansii*[W], *E. pycnantha*, *E. retorta*, *E. ribisaria*, *E. salax*, *E. squarrosa*, *E. stokoeanthus*[W], *E. stokoei*, *E. suffulta*, *E. thomae*, *E. truncata*, *E. tubercularis*, *E. vallisaranearum*, *E. viridimontana* subsp. *nivicola*, *E. viridimontana* subsp. *viridimontana*, *E. viscaria* subsp. *gallorum*, *Euchaetis glabra*, *Euryops indecorus*, *Glischrocolla formosa*, *Grubbia rourkei*, *Heliophila ramosissima*, *Klattia flava*, *K. stokoei*, *Leucospermum cordatum*, *Liparia bonaespei*, *L. boucheri*, *Metalasia confusa*, *M. humilis*, *M. lichtensteinii*, *M. quinqueflora*, *Mimetes capitulatus*, *M. stokoei* (extinct in wild), *Muraltia aciphylla*, *M. aspalatha*, *M. asparagifolia*, *M. capensis*, *M. chamaepitys*, *M. guthriei*, *M. hyssopifolia*, *M. occidentalis*, *M. paludosa*, *M. pubescens*, *M. stokoei*, *M. vulpina*, *Nivenia concinna*, *N. levynsiae*, *N. stokoei*, *Osmitopsis glabra*, *O. parvifolia*, *Paranomus spicatus*, *Phylica guthriei*, *P. linifolia*, *P. variabilis*, *Prismatocarpus cordifolius*, *Rafnia racemosa* subsp. *pumila*, *Raspalia globosa*, *Senecio speciosissimum*[W], *Serruria deluvialis*, *Sonderothamnus petraeus*, *Sorocephalus clavigerus*, *S. palustris*[W], *S. tenuifolius*, *Spatalla mollis*[W], *S. prolifera*[W], *Staavia brownii*, *Stylapterus barbatus*, *S. micranthus*, *Syncarpha lepidopodium*, *Thaminophyllum multiflorum*, *Ursinia eckloniana*[W]. Succulent Shrubs: *Lampranthus middlemostii*, *L. wordsworthiae*, *Ruschia lavisii*. Semiparasitic Shrubs: *Thesium brachygyne*, *T. quinqueflorum*. Herbs: *Centella pilosa*, *Charadrophila capensis*[W], *Galium rourkei*, *Peucedanum triternatum*. Geophytic Herbs: *Agapanthus walshii*, *Disa begleyi*, *D. brevipetala*, *Geissorhiza lithicola*, *Gladiolus nerineoides*, *Ixia esterhuyseniae*, *Watsonia distans*[W]. Carnivorous Herb: *Drosera esterhuyseniae*[W]. Graminoids: *Restio bifarius* (d), *Askidiosperma esterhuyseniae*, *Calopsis nudiflora*, *C. sparsa*, *Ficinia minutiflora*, *Hypodiscus alternans*, *Ischyrolepis saxatilis*, *Restio distans*, *R. fusiformis*, *R. involutus*, *R. nuwebergensis*, *R. verrucosus*, *Tetraria crassa*, *Willdenowia purpurea*, *W. rugosa*.

Conservation Least threatened. Target 30%. The unit is statutorily well conserved (58%) in the Hottentots Holland and Groenlandberg Nature Reserves and especially in the Kogelberg Biosphere Reserve (including Kogelberg and Kleinmond Nature Reserves). An additional 18% protected in the Hottentots-Holland Mountains catchment area. Some 17% transformed (pine plantations, cultivation, urban sprawl and spread of informal settlements). Aliens *Pinus pinaster* and *Hakea sericea* have been targeted for clearing, but remain of concern in some areas. Erosion very low.

Remark 1 Vegetation of this unit was reasonably well surveyed at Kogelberg, Jonkershoek, Jakkalshoek and Haasvlakte. Data suggest that this vegetation unit might perhaps be divided into two or three units, but the boundaries are not obvious—Sir Lowry's and Viljoen's Passes appear to be the boundary of a northern Jonkershoek subunit, and the Kogelberg subunit may perhaps be further subdivided with a northern Groenlandberg subunit separated between the Highlands and Houwhoek Passes. However, at present there are insufficient data to verify this.

Remark 2 In this unit, more than any other, Sandstone Fynbos communities are floristically quite distinctive in that local patches may be dominated by species that are rare in similar communities elsewhere. Matching communities floristically from similar habitats across the region is therefore very difficult. Even structural types vary from ericaceous to restioid to proteoid across matched habitats for no obviously discernable reasons.

Remark 3 This is the heart of the Cape flora—a true crown jewel of the temperate flora of the world. The species-level endemism is staggering and this unit contains two endemic genera, *Charadrophila* (still unclear whether Stilbaceae or Scrophulariaceae) and *Glischrocolla* (Penaeaceae). Monotypic genera occurring also outside this unit include *Atrichantha*, *Audouinia*, *Bryomorphe*, *Capeobolus*, *Empleuridium*, *Euthystachys*, *Evotella*, *Glia*, *Itasina*, *Lanaria*, *Mystropetalon*, *Neesenbeckia*, *Oreoleysera*, *Phaenocoma*, *Saltera* and *Witsenia*. Endemic Cape genera such as *Retzia*, *Orothamnus*, *Pillansia* and *Sonderothamnus* are shared only with FFs 12 Overberg Sandstone Fynbos. Genera such as *Anaxeton*, *Aulax*, *Bolusafra*, *Brunia*, *Capelio*, *Calopsis*, *Chrysitrix*, *Cliffortia*, *Diastella*, *Dilatris*, *Disa*, *Elegia*, *Erica*, *Euryops*, *Grubbia*, *Helichrysum*, *Hermas*, *Hypocalyptus*, *Klattia*, *Liparia*, *Metalasia*, *Mimetes*, *Muraltia*, *Oldenburgia*, *Osmitopsis*, *Prismatocarpus*, *Protea*, *Raspalia*, *Restio*, *Siphocodon*, *Spatalla*, *Staavia*, *Syncarpha*, *Thaminophyllum*, *Thesium*, *Ursinia* and *Wachendorfia* are either remarkably species-rich in this unit or have most of the

extant species of the genus in this area. The unit contains representatives of almost all endemic families of the CFR (or of the Cape Floristic Kingdom) (the only notable exception being Geissolomataceae of the Langeberg). Many of the endemics are confined to vulnerable wetland habitats (mainly seeps) or are found in sheltered rocky habitats such as on steep cliffs. Many species still await formal description.

Remark 4 Shale bands are a prominent feature in the landscape, with areas below the shale band predominantly proteoid fynbos, whereas above the shale band ericaceous and restioid fynbos predominate. It is unclear whether this is due to the Nardouw sandstones being relatively nutrient-poor compared to the Peninsula sandstones, or due to nutrient input from the shale.

References Van der Merwe (1962, 1966), Boucher (1972, 1977, 1978, 1988a, 1996b), Werger et al. (1972a, b), Kruger (1979), Durand (1981), Burman & Bean (1985), McDonald (1985, 1987, 1988), Davis (1988), Boucher & Stindt (1992), Sieben (2003), Sieben et al. (2004), Bean & Johns (2005).

FFs 12 Overberg Sandstone Fynbos

VT 69 Macchia (64%), VT 47 Coastal Macchia (31%) (Acocks 1953). Mesic Mountain Fynbos (85%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (85%) (Low & Rebelo 1996). BHU 13 Springfield Sand Plain Fynbos (25%), BHU 57 Klein River Mountain Fynbos Complex (25%), Bredasdorp Mountain Fynbos Complex (23%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Spread irregularly from Bot River and Hawston in the northwest to the Soetanysberg and Bredasdorp in the southeast, including the Caledon Swartberg, Babilonstoring, Kleinrivier and Bredasdorp Mountains and Agulhas hills such as Franskraal se Berge and Buffeljachtsberg. Altitude 20–1 167 m on the summit of Babilonstoringberg.

Vegetation & Landscape Features Low mountains, undulating hills and moderately undulating plains supporting moderately tall, dense restioid, ericoid-leaved and proteoid shrublands. Structurally these are mainly proteoid and ericaceous fynbos, with restioid fynbos also occurring locally.

Geology & Soils Acidic lithosol soils derived from Ordovician sandstones of the Table Mountain Group (Cape Supergroup), Houwhoek, Glenrosa and Mispah forms prominent. Land types mainly Ib and Gb.

L. Mucina

Figure 4.34 FFs 12 Overberg Sandstone Fynbos: Proteoid fynbos with *Protea compacta* and *Leucadendron xanthoconus* on deep acid sands overlying Table Mountain sandstones near Elim (Western Cape).

Climate MAP 450–830 mm (mean: 585 mm), peaking May to August. Southeasterly cloud brings mist precipitation to eastern and southern slopes at higher altitudes in summer. Mean daily maximum and minimum temperatures 25.6°C and 6.3°C for January and July, respectively. Frost incidence 2 or 3 days per year. See also climate diagram for FFs 12 Overberg Sandstone Fynbos (Figure 4.21).

Important Taxa ([W]Wetlands) Small Tree: *Leucospermum conocarpodendron* subsp. *viridum*. Tall Shrubs: *Protea repens* (d), *Euryops abrotanifolius*, *Passerina corymbosa*, *Protea compacta*. Low Shrubs: *Erica globiceps* subsp. *globiceps* (d), *E. pulchella* (d), *Phaenocoma prolifera* (d), *Serruria fasciflora* (d), *Agathosma serpyllacea*, *Aspalathus angustifolia* subsp. *angustifolia*, *A. aspalathoides*, *A. caledonensis*, *A. callosa*, *A. dunsdoniana*, *A. elliptica*, *A. intervallaris*, *A. marginata*, *A. oblongifolia*, *A. pachyloba* subsp. *pachyloba*, *A. psoraleoides*, *A. quinquefolia* subsp. *compacta*, *A. ramulosa*, *A. retroflexa* subsp. *retroflexa*, *A. securifolia*, *Aulax umbellata*, *Brunia laevis*, *Campylostachys cernua*, *Cliffortia ferruginea*, *Erica coccinea* subsp. *coccinea*, *E. corifolia*, *E. nudiflora*, *E. plukenetii* subsp. *plukenetii*, *E. regia* subsp. *regia*, *E. serrata*, *E. sessiliflora*, *E. similis*, *E. vestita*, *E. viscaria* subsp. *longifolia*, *Grubbia rosmarinifolia*, *Leucadendron salignum* (d), *L. gandogeri* (d), *L. laureolum*, *L. platyspermum*, *L. tinctum*, *L. xanthoconus*, *Leucospermum cordifolium*, *L. prostratum*, *L. truncatulum*, *Linconia cuspidata*, *Lobostemon sanguineus*, *Metalasia brevifolia*, *M. erubescens*, *M. inversa*, *Mimetes cucullatus*, *Muraltia collina*, *Nebelia paleacea*, *Passerina truncata* subsp. *monticola*, *Phylica brevifolia*, *P. imberbis*, *Protea angustata*, *P. aspera*, *P. cordata*, *P. cynaroides*, *P. longifolia*, *P. speciosa*, *Retzia capensis*, *Roella incurva*, *Serruria elongata*, *S. flagellifolia*, *S. heterophylla*, *S. rostellaris*, *S. rubricaulis*, *Spatalla curvifolia*, *S. racemosa*, *Staavia radiata*, *Stoebe aethiopica*, *S. capitata*, *Ursinia paleacea*, *U. quinquepartita*[W], *Zyrphelis foliosa*, *Z. lasiocarpa*. Pseudocarnivorous Shrub: *Roridula gorgonias*. Herbs: *Edmondia sesamoides* (d), *Mairia burchellii*, *M. coriacea*. Geophytic Herbs: *Lanaria lanata* (d), *Geissorhiza cataractarum*[W], *G. hesperanthoides*, *G. hispidula*, *G. imbricata* subsp. *imbricata*[W], *G. juncea*, *G. parva*, *G. schinzii*, *G. similis*, *Romulea dichotoma*, *R. gracillima*, *R. triflora*. Graminoids: *Mastersiella digitata* (d), *Calopsis hyalina*, *C. membranacea*, *Ceratocaryum argenteum*, *Cyathocoma hexandra*[W], *Elegia deusta*, *E. filacea*, *E. juncea*, *E. persistens*, *E. recta*, *E. tectorum*, *Ficinia tristachya*, *Hypodiscus argenteus*, *Ischyrolepis capensis*, *Restio dodii*[W], *R. similis*, *Rhodocoma fruticosa*, *Staberoha cernua*, *S. multispicula*, *Tetraria bromoides*, *T. capillacea*, *T. compar*, *T. cuspidata*, *T. fasciata*, *T. thermalis*, *Thamnochortus erectus*, *T. guthrieae*.

Endemic Taxa ([W]Wetlands) Tall Shrubs: *Aspalathus excelsa*, *Cliffortia curvifolia*, *Erica perspicua* var. *latifolia*[W], *Indigofera superba*. Low Shrubs: *Adenandra lasiantha*, *A. schlechteri*, *Amphithalea rostrata*, *A. speciosa*, *Aspalathus chenopoda* subsp. *gracilis*, *A. juniperina* subsp. *grandis*, *A. rosea*, *Berzelia incurva*, *B. rubra*, *Brachysiphon rupestris*, *Cliffortia geniculata*, *C. monophylla*, *C. tenuis*, *Erica agglutinans*, *E. ampullacea*, *E. aristata*, *E. axilliflora*, *E. banksii* subsp. *purpurea*, *E. bodkinii*[W], *E. chonantha*, *E. collina*, *E. colorans*[W], *E. crateriformis*, *E. ecklonii*, *E. erina*, *E. filipendula*, *E. flavicoma*, *E. galpinii*, *E. gerhardii*, *E. grisbrookii*, *E. hendricksei*[W], *E. hermani*, *E. innovans*, *E. irbyana*, *E. lageniformis*, *E. lanuginosa*, *E.*

latituba, *E. longiaristata*, *E. melanacme*, *E. nigrimontana*, *E. oligantha*[W], *E. oliveri*, *E. pauciovulata*[W], *E. penduliflora*, *E. plena*[W], *E. pogonanthera*, *E. pulchelliflora*, *E. russakiana*, *E. shannonea*, *E. tenella*, *E. trichophora*[W], *E. turrisbabylonica*[W], *E. venustiflora* subsp. *venustiflora*, *E. villosa*, *E. vogelpoelii*, *E. williamsiorum*, *E. xeranthemifolia*, *Euryops lasiocladus*, *E. tenuilobus*, *Gnidia sonderiana*, *Lachnaea aurea*, *Leucospermum gracile*, *Macrostylis cauliflora*, *Metalasia bodkinii*, *M. cymbifolia*, *M. seriphiifolia*, *M. serrata*, *Mimetes palustris*, *Muraltia gillettiae*, *M. spicata*, *Osteospermum elsieae*, *Otholobium dreweae*, *Phylica floribunda*, *Prismatocarpus fastigiatus*, *Pseudobaeckea stokoei*, *Rhigiophyllum squarrosum*[W], *Serruria meisneriana*, *S. rebeloi*, *Sonderothamnus speciosus*, *Spatalla squamata*, *Thaminophyllum latifolium*, *Zyrphelis spathulata*. Succulent Shrubs: *Acrodon quarcicola*, *Delosperma guthriei*, *Erepsia babiloniae*, *E. oxysepala*, *E. polypetala*, *Lampranthus framesii*. Semiparasitic Shrubs: *Thesium bathyschistum*, *T. fallax*, *T. sertulariastrum*. Herbs: *Arctotis schlechteri*, *Centella rupestris*, *Pseudoselago pulchra*. Geophytic Herbs: *Aristea palustris*[W], *Cyrtanthus guthrieae*, *Geissorhiza bryicola*[W], *Gladiolus overbergensis*, *Lachenalia sargeantii*, *Moraea barnardii*, *M. longiaristata*, *M. vallisavium*, *Tritoniopsis williamsiana*. Carnivorous Herb: *Drosera slackii*[W]. Graminoids: *Ceratocaryum pulchrum*, *Elegia decipiens*, *Ficinia dura*, *Pentaschistis scandens*, *Restio scaber*.

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Figure 4.35 FFs 13 North Sonderend Sandstone Fynbos: Rugged midslopes and plateaus of the Riviersonderend Mountains on Jonaskop (Western Cape), with restioid fynbos dominated by *Elegia racemosa* in the foreground.

Conservation Least threatened. Target 30%. Only 6% statutorily conserved in the Agulhas National Park, Fernkloof, Babilonstoring, Heuningberg, Maanschynkop, Salmonsdam and Caledon Nature Reserves. Additional area protected in private conservation areas such as Vogelgat, Brandfontein, Jan Malherbe, Groothagelkraal, Fynbosrand, Brandfontein-Rietfontein and Waterfall. About 6% transformed (cultivation). Alien *Pinus pinaster*, *Acacia cyclops*, *A. saligna*, *Hakea sericea*, *H. gibbosa* and *Leptospermum laevigatum* occur in places. Erosion very low and low.

Remarks The Babylonstoring and Kleinrivier Mountains have many local endemic taxa and could perhaps be separated (together with Caledon Swartberg) at the Klein River as a separate unit. There are no reliable data to suggest that the Caledon Swartberg warrants a separate unit, unlike Piketberg and Potberg. More data and further research are needed.

References Cowling et al. (1988), Thwaites & Cowling (1988), De Lange (1992), Richards (1994), Richards et al. (1995, 1997a, b), Mustart et al. (1997).

FFs 13 North Sonderend Sandstone Fynbos

VT 69 Macchia (82%) (Acocks 1953). Mesic Mountain Fynbos (45%), Dry Mountain Fynbos (37%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (83%) (Low & Rebelo 1996). BHU 59 Riviersonderend Mountain Fynbos Complex (84%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Northern slopes of the Riviersonderend Mountains from Villiersdorp to Bromberg and Luiperdsberg east of Stormsvlei, including Klipberg and Sandberg towards Robertson. Altitude from 150 m, with the highest peaks exceeding 1 600 m (Jonaskop, Pilaarkop and an unnamed peak).

Vegetation & Landscape Features Gentle to steep north-facing slopes, highly dissected in a few places, with a midslope sandy plateau and extensive gentle lower slopes. Vegetation is an open, tall, proteoid-leaved evergreen shrubland with a dense moderately tall, ericoid-leaved shrubland as understorey. This is mainly asteraceous fynbos on the western and lower slopes, but extensive proteoid and restioid fynbos dominate the middle slopes. Ericaceous fynbos is restricted to the highest peaks. This unit (in facies with extensive asteraceous fynbos—with emergent *Aloe ferox*) borders on succulent karoo shrublands at the lowest elevations and to the east. The deep sand habitat of the northern plateau, which runs along the length of the mountain, is a distinctive feature associated with many endemic species.

Geology & Soils Acidic lithosol soils derived from Ordovician sandstones of the Table Mountain Group (Cape Supergroup). Land types mainly Ic.

Climate MAP 250–1 410 mm (mean: 605 mm), peaking May to August. Mean daily maximum and minimum temperatures 26.2°C and 4.4°C for February and July, respectively. Frost incidence 7–10 days per year. See also climate diagram for FFs 13 North Sonderend Sandstone Fynbos (Figure 4.21).

Important Taxa ([T]Cape thickets) Small Trees: *Acacia karroo*, *Cunonia capensis*[T], *Metrosideros angustifolia*[T], *Protea nitida*. Tall Shrubs: *Protea neriifolia* (d), *P. repens* (d), *Polygala fruticosa*, *Protea laurifolia*, *Rhus pyroides*[T]. Low Shrubs: *Agathosma leptospermoides*, *Athanasia oocephala*, *Cliffortia ruscifolia*, *Elytropappus glandulosus*, *Erica denticulata*, *E. globiceps* subsp. *zeyheri*, *E. jonasiana*, *E. lateralis*, *E. modesta*, *E. plukenetii* subsp. *plukenetii*, *E. serrata*, *E. taxifolia*, *E. vestita*, *Leucadendron laureolum*, *L. microcephalum*, *L. salignum*, *Leucospermum calligerum*, *Muraltia ferox*, *Paranomus adiantifolius*, *P. capitatus*, *Passerina burchellii*, *Phaenocoma prolifera*, *Prismatocarpus lycioides*, *Protea amplexicaulis*, *P. cynaroides*, *P. humiflora*, *P. lorifolia*, *P. scabra*, *P. subulifolia*, *Serruria gremialis*, *S. viridifolia*, *Stoebe spiralis*. Succulent Shrubs: *Drosanthemum leptum*, *Ruschia acutangula*. Herbs: *Edmondia sesamoides*, *Ursinia oreogena*. Geophytic Herb: *Gladiolus atropictus*. Graminoids: *Ehrharta ramosa* subsp. *aphylla*, *Hypodiscus squamosus*, *H. striatus*, *Ischyrolepis capensis*, *I. distracta*, *I. gaudichaudiana*, *Pentaschistis eriostoma*, *Restio filiformis*, *Thamnochortus cinereus*.

Endemic Taxa Low Shrubs: *Leucadendron burchellii*, *L. immoderatum*, *L. nervosum*, *Leucospermum harpagonatum*, *Serruria stellata*, *S. williamsii*, *Spatalla argentea*.

Conservation Least threatened. Target 30%. Statutorily conserved (21%) in the Riviersonderend Nature Reserve, with an additional 51% mainly in a private conservation area of the same name. Only 2% transformed by cultivation for protea nurseries and fruit orchards—these being on the deep sand habitat of the northern plateau supporting many threatened taxa. The threat of transformation in this area is serious since none of the deep-sand northern plateau is under formal conservation. Alien *Pinus pinaster* and *Hakea sericea* occasionally occur over about half of the area. Erosion is very low.

Remark 1 The northern slopes of the Riviersonderend Mountains is a poorly explored area. The data of the Protea Atlas Project suggest that the sandstone units FFs 13 and FFs 14 (see below) form the centre of specific diversity in Proteaceae; especially the genus *Serruria* is very speciose here. This may well be found to be true of other genera and families after more exploration. *Endonema* (Penaeaceae) is endemic to the Riviersonderend.

Remark 2 Jonaskop (1 646 m) and the slopes facing the renosterveld and karoo regions to the north have become the focus of observational and experimental research into a range of ecological questions along the elevational gradient. These studies include work on plant functional types, phenology, transplant experiments and predictions of the effects of climate change.

References Rutherford (1978), Agenbag & Esler (2004a, b), Agenbag et al. (2004), Vile et al. (2005), C. Boucher (unpublished data), Protea Atlas Project (unpublished data).

FFs 14 South Sonderend Sandstone Fynbos

VT 69 Macchia (87%) (Acocks 1953). Mesic Mountain Fynbos (77%), South West Coast Renosterveld (11%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (79%) (Low & Rebelo 1996). BHU 59 Riviersonderend Mountain Fynbos Complex (73%), BHU 18 Genadendal Grassy Fynbos (22%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Southern slopes of the Riviersonderend Mountains from Villiersdorp and Eseljagsberg in the west to Stormsvlei in the east. Altitude from 200 m, with the highest peaks exceeding 1 600 m (Jonaskop, Pilaarkop and an unnamed peak).

Vegetation & Landscape Features Steep to gentle southern slopes, with extensive cliffs in places. Vegetation a moderately tall, dense ericoid-leaved shrubland with open emergent proteoids. Ericaceous and restioid fynbos most common, with proteoid fynbos found mainly on lower slopes.

Geology & Soils Acidic lithosol soils derived from Ordovician sandstones of the Table Mountain Group (Cape Supergroup). Land types mainly Ib, Ic and Fa.

Climate MAP 380–1 650 mm (mean: 785 mm), peaking May to August. Southeasterly cloud brings heavy mist precipitation at higher altitudes in summer. Mean daily maximum and minimum monthly temperatures 25.7°C and 4.6°C for February and July, respectively. Frost incidence 3–10 days per year. See also climate diagram for FFs 14 Sonderend Sandstone Fynbos (Figure 4.21).

Important Taxa ([W]Wetlands) Small Tree: *Protea nitida* (d). Tall Shrubs: *Protea neriifolia* (d), *P. repens* (d), *Leucadendron salicifolium*. Low Shrubs: *Leucadendron salignum* (d), *Ursinia pinnata* (d), *Amphithalea ericifolia* subsp. *scoparia*, *Aspalathus ramulosa*, *A. stenophylla*, *Aulax cancellata*, *Erica hispidula*, *E. lutea*, *E. multumbellifera*, *E. sessiliflora*, *E. taxifolia*, *E. transparens*, *Leucadendron microcephalum*, *L. spissifolium* subsp. *spissifolium*, *Metalasia tenuifolia*, *Mimetes cucullatus*, *Passerina burchellii*, *Protea amplexicaulis*, *P. cynaroides*, *P. scabra*, *P. subulifolia*, *Raspalia microphylla*, *Spatalla propinqua*[W], *Ursinia scariosa* subsp. *subhirsuta*. Succulent Shrub: *Acrodon subulatus*. Herb: *Edmondia pinifolia*. Geophytic Herb: *Geissorhiza grandiflora*. Graminoids: *Elegia aggregata*, *E. grandis*[W].

Endemic Taxa ([W]Wetlands) Tall Shrub: *Endonema lateriflora*[W]. Low Shrubs: *Erica trichophylla* (d), *Adenandra gracilis*, *Amphithalea ericifolia* subsp. *minuta*, *Anaxeton brevipes*, *Aspalathus taylorii*, *Athanasia scabra*, *Cliffortia crenulata*, *C. pungens*, *Diosma fallax*, *D. pilosa*, *D. thyrsophora*, *Endonema retzioides*, *Erica accommodata*, *E. alfredii*, *E. botryoides*, *E. caledonica*, *E. columnaris*, *E. diotiflora*, *E. embothriifolia*, *E. galgebergensis*, *E. goatcheriana* var. *petrensis*, *E. ignita*, *E. insolitanthera*, *E. lachnaeifolia*, *E. lanipes*, *E. lawsonia*, *E. oakesiorum*, *E. orthiocola*[W], *E. ovina*, *E. pannosa*, *E. pellucida*, *E. perlata*, *E. permutata*, *E. petricola*, *E. physophylla*, *E. pilaarkopensis*, *E. polycoma*, *E. praenitens*, *E. remota*, *E. rufescens*, *E. rupicola*, *E. sicifolia*, *E. tomentosa*, *E. vallis-gratiae*, *E. xanthina*, *Euryops longipes* var. *longipes*, *Gymnostephium angustifolium*, *G. corymbosum*, *G. hirsutum*, *Helichrysum rotundatum*, *Indigofera quinquefolia*, *Lachnaea greytonensis*, *L. pudens*, *Linconia ericoides*, *Lonchostoma esterhuyseniae*, *Metalasia alfredii*, *M. tenuis*[W], *Muraltia concava*, *M. tenuifolia*, *Nebelia laevis*, *Nivenia dispar*, *Pelargonium divisifolium*, *Phylica burchellii*, *P. lucens*, *P. stenantha*, *P. tubulosa*, *Senecio coleophyllus*, *S. retortus*, *Sorocephalus alopecurus*, *S. crassifolius*[W], *S. pinifolius*, *Staavia zeyheri*, *Stilbe serrulata*. Succulent Shrub: *Lampranthus vallis-gratiae*. Herbs: *Centella cryptocarpa*, *C. dolichocarpa*, *C. thesioides*, *Helichrysum marifolium*, *Pseudoselago prostrata*. Geophytic Herbs: *Babiana foliosa*, *Gladiolus stokoei*, *Nerine pudica*, *Ornithogalum oreo-*

L. Mucina

Figure 4.36 FFs 14 South Sonderend Sandstone Fynbos: Deep valley of the Baviaanskloof near Genadendal (Western Cape) showing a mosaic of mainly restioid fynbos on the slopes, riparian thickets along the river and small relict patches of afrotemperate forests below the steep slopes of Jonaskop.

genes, *Thereianthus montanus*, *Watsonia minima*. Graminoids: *Nevillea singularis*, *Restio ingens*.

Conservation Least threatened. Target 30%. Statutorily conserved (40%) in the Riviersonderend Nature Reserve, with an additional 39% mainly in a private conservation area carrying the same name. Only 7% transformed (cultivation, pine plantations). Alien *Hakea sericea* and *Pinus pinaster* occur occasionally, the latter in very dense stands between Genadendal and Jonaskop. Erosion very low.

Remarks To date this vegetation has not received attention from vegetation ecologists and it remains floristically poorly described. The distribution data on Proteaceae (Protea Atlas Project) suggest that the eastern end of this unit has affinities with FFs 16 South Langeberg Sandstone Fynbos, whereas the western edge shares many species with FFs 10 Hawequas Sandstone Fynbos, the boundary being around Pilaarkop above Riviersonderend.

Reference Protea Atlas Project (unpublished data).

FFs 15 North Langeberg Sandstone Fynbos

VT 70 False Macchia (47%), VT 69 Macchia (24%) (Acocks 1953). Mesic Mountain Fynbos (30%), Dry Mountain Fynbos (30%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (67%) (Low & Rebelo 1996). BHU 64 Southern Langeberg Mountain Fynbos Complex (46%), BHU 60 Koo Langeberg Mountain Fynbos Complex (20%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Northern slopes of the Langeberg from the Keerom Mountains near Worcester in the west to Cloete's Pass north of Albertinia in the east, and to the interior on the Waboomsberg and Warmwaterberg Mountains north of Montagu and Barrydale, respectively. Also includes Aasvoëlberg hills from Albertinia to Mossel Bay. Altitude range very broad, 100–1 800 m, with several high peaks such as Misty Point (1 709 m) and Grootberg (1 637 m), generally higher in the west than the east. FFs 30 Western Altimontane Sandstone Fynbos on the western peaks above 1 800 m.

Vegetation & Landscape Features Gentle to steep, north-facing slopes, not much dissected over much of the range. Surface is gently sloping foothills of Waboomsberg, Warmwaterberg and Aasvoëlberg. The Cedarberg Shale Band is prominent in the west, mainly as a smooth-sided valley, along which most of the hiking trails are orientated. Vegetation is mainly proteoid and restioid fynbos, with ericaceous fynbos at higher altitudes and asteraceous fynbos on the lower slopes. Old African surface conglomerates (mapped as part of this unit) on the lower slopes have asteraceous fynbos dominated by *Dodonaea viscosa* var. *angustifolia*. Ravines support Cape thicket, dominated by *Buddleja saligna*, and species of *Pelargonium*, *Rhus* and *Salvia*.

Geology & Soils Acidic lithosol soils derived from Ordovician sandstones of the Table Mountain Group (Cape Supergroup). Land types mainly Ic, Ib, Db and Fc.

Climate MAP 250–1 200 mm (mean: 580 mm), peaking very slightly in winter and with a slight low from December to February. Mean daily maximum and minimum temperatures 26.5°C and 4.1°C for January and July, respectively. Frost incidence 3–20 days per year. See also climate diagram for FFs 15 North Langeberg Sandstone Fynbos (Figure 4.21).

Important Taxa ([W]Wetlands) Small Tree: *Protea nitida* (d). Tall Shrubs: *Leucadendron eucalyptifolium* (d), *Metalasia densa* (d), *Protea neriifolia* (d), *P. repens* (d), *Chrysanthemoides monilifera*, *Dodonaea viscosa* var. *angustifolia*, *Protea eximia*, *Psoralea pinnata*[W]. Low Shrubs: *Agathosma ovata* (d), *Diosma tenella* (d), *Erica anguliger* (d), *E. hispidula* (d), *E. melanthera* (d), *E. rosacea* subsp. *rosacea* (d), *E. versicolor* (d), *Leucadendron salignum* (d), *Leucospermum calligerum* (d), *Passerina obtusifolia* (d), *Phylica pinea* (d), *Agathosma cerefolium*, *Anthospermum spathulatum* subsp. *spathulatum*, *Aspalathus granulata*, *A. inops*, *A. vulpina*, *Berzelia galpinii*[W], *Brunia macrocephala*, *Cyclopia bowieana*, *Elytropappus hispidus*, *Erica articularis*, *E. coarctata*, *E. cubica*, *E. tenuis*, *Euryops pinnatipartitus*, *Gnidia francisci*, *Indigofera pappei*, *Leucadendron cordatum*, *Leucospermum cuneiforme*, *L. mundii*, *Lobelia capillifolia*, *Lobostemon decorus*, *Metalasia massonii*, *M. pulcherrima* f. *pallescens*, *Mimetes cucullatus*, *Muraltia heisteria*, *Paranomus candicans*, *Penaea cneorum* subsp. *ruscifolia*, *Phaenocoma prolifera*, *Phylica axillaris*, *Protea aspera*, *P. lorifolia*, *Stoebe aethiopica*, *S. cinerea*, *S. saxatilis*, *Syncarpha milleflora*, *Ursinia hispida*, *U. rigidula*, *Wahlenbergia tenella*. Succulent Shrubs: *Adromischus triflorus*, *Crassula atropurpurea* var. *atropurpurea*, *Machairophyllum albidum*, *Oscularia deltoides*, *Senecio aizoides*. Woody Succulent Climber: *Zygophyllum fulvum*. Semiparasitic Shrub: *Thesium subnudum*. Herbs: *Lobelia pubescens* var. *pubescens* (d), *Centella virgata*, *Linum gracile*, *Peucedanum ferulaceum*, *Polygala refracta*, *Ursinia nudicaulis*. Geophytic Herbs: *Lanaria lanata* (d), *Aristea racemosa*. Herbaceous Parasitic Climber: *Cassytha ciliolata*. Graminoids: *Ceratocaryum decipiens* (d), *Ehrharta dura* (d), *E. ramosa* subsp. *aphylla* (d), *Elegia filacea* (d), *E. galpinii* (d), *Heteropogon contortus* (d), *Hypodiscus argenteus* (d), *H. aristatus* (d), *H. striatus* (d), *Merxmuellera decora* (d), *Pentaschistis colorata* (d), *P. eriostoma* (d), *Restio filiformis* (d), *R. inconspicuus* (d), *Staberoha cernua* (d), *Tetraria bromoides* (d), *T. flexuosa* (d), *T. ustulata* (d), *Willdenowia bolusii* (d), *Calopsis filiformis*, *C. rigida*, *Cannomois parviflora*, *Elegia asperiflora*, *Ficinia acuminata*, *F. laciniata*, *F. trichodes*, *Hypodiscus laevigatus*, *H. montanus*, *Ischyrolepis capensis*, *I. sieberi*, *Mastersiella purpurea*, *Pentameris macrocalycina*, *Pentaschistis malouinensis*, *Restio peculiaris*, *R. stric-*

L. Mucina

Figure 4.37 FFs 15 North Langeberg Sandstone Fynbos: Dry proteoid fynbos dominated by *Protea punctata* on upper slopes of the Langeberg facing the Koo, west of Montagu (Western Cape).

tus, *R. triticeus*, *Rhodocoma fruticosa*, *Tetraria involucrata*, *T. thermalis*, *Thamnochortus cinereus*.

Endemic Taxa ([W]Wetlands) Low Shrubs: *Serruria balanocephala* (d), *Acmadenia latifolia*, *A. nivenii*, *A. trigona*, *Amphithalea cymbifolia*, *Anderbergia fallax*, *Aspalathus longifolia*, *A. verbasciformis*, *Cliffortia alata*, *C. pulchella*, *Clutia govaertsii*, *Erica atropurpurea*[W], *E. barrydalensis*, *E. chlorosepala*, *E. gigantea*, *E. langebergensis*, *E. leucodesmia*, *E. rhodantha*, *E. rudolfii*, *Felicia cana*, *F. comptonii*, *Leucospermum erubescens*, *L. saxatile*, *Lobostemon muirii*, *Lotononis purpurescens*, *Metalasia galpinii*, *Paranomus spathulatus*, *Pelargonium denticulatum*, *Phylica brachycephala*, *P. mairei*, *Polygala langebergensis*, *Prismatocarpus lasiophyllus*, *Protea holosericea*, *Wahlenbergia fruticosa*, *W. oligantha*. Succulent Shrubs: *Antimima verrucosula*, *Drosanthemum croceum*, *Erepsia polita*, *Lampranthus laetus*, *L. marcidulus*, *L. verecundus*. Geophytic Herbs: *Disa schlechteriana*, *Ixia stolonifera*. Graminoids: *Platycaulos acutus*, *Restio implicatus*, *R. perseverans*, *Thamnochortus amoena*, *T. ellipticus*, *T. karooica*.

Conservation Least threatened. Target 30%. Statutorily conserved (13%) in the Boosmansbos Wilderness Area, with an additional 45% in mountain catchment areas such as Langeberg-oos, Langeberg-wes and Matroosberg. Some 8% transformed (cultivation). Aliens include *Pinus pinaster*, *Hakea sericea* and *Acacia mearnsii*. Erosion very low and moderate.

Remark 1 The eastern boundary of North Langeberg Sandstone Fynbos has been set at Cloete's Pass, but could equally well have been set at Robinson Pass. The area between the Robinson and Cloete's Passes has at least two near endemic Proteaceae (*Leucospermum saxatile, Paranomus longicaulis*), which extend west of the Gouritz River gap. More data are needed to determine an optimal boundary between the North Langeberg Sandstone Fynbos and FFs 18 North Outeniqua Sandstone Fynbos based on species distributions and associated vegetation patterns.

Remark 2 The coastal range of the Aasvoëlberg, although isolated, clearly fits within FFs 15 North Langeberg Sandstone Fynbos. However, we have tentatively included the southern slopes of the Aasvoëlberg within this unit, pending further investigation.

References Muir (1929), McDonald (1993a, b, c, 1995, 1999), McDonald et al. (1995, 1996).

FFs 16 South Langeberg Sandstone Fynbos

VT 70 False Macchia (51%), VT 69 Macchia (26%) (Acocks 1953). Mesic Mountain Fynbos (61%), Dry Mountain Fynbos (24%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (89%) (Low & Rebelo 1996). BHU 64 Southern Langeberg Mountain Fynbos Complex (56%), BHU 64 Koo Langeberg Mountain Fynbos Complex (30%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Southern slopes of the Langeberg from the Keerom Mountains near Worcester to Cloete's Pass north of Albertinia, Waboomsberg (north of Montagu), Warmwaterberg (north of Barrydale) and Amandelbosberg (northeast of Heidelberg) Mountains. Altitude 200–1 800 m with several high peaks such as Misty Point (1 709 m) and Grootberg (1 637 m), generally higher in the west than the east. FFs 30 Western Altimontane Sandstone Fynbos on the western peaks above 1 800 m.

Vegetation & Landscape Features Complex of gentle to very steep, south-facing slopes, not much dissected over most of the range, but deeply dissected in parts. The Cedarberg Shale Band is prominent in the east, in an almost vertical orientation, as a narrow, smooth-sided valley along which the hiking trails are orientated. Ericaceous and restioid fynbos predominate at higher altitudes, with moderately tall to tall proteoid fynbos on middle and lower slopes. Scrub and restioid fynbos are found in habitats with much groundwater.

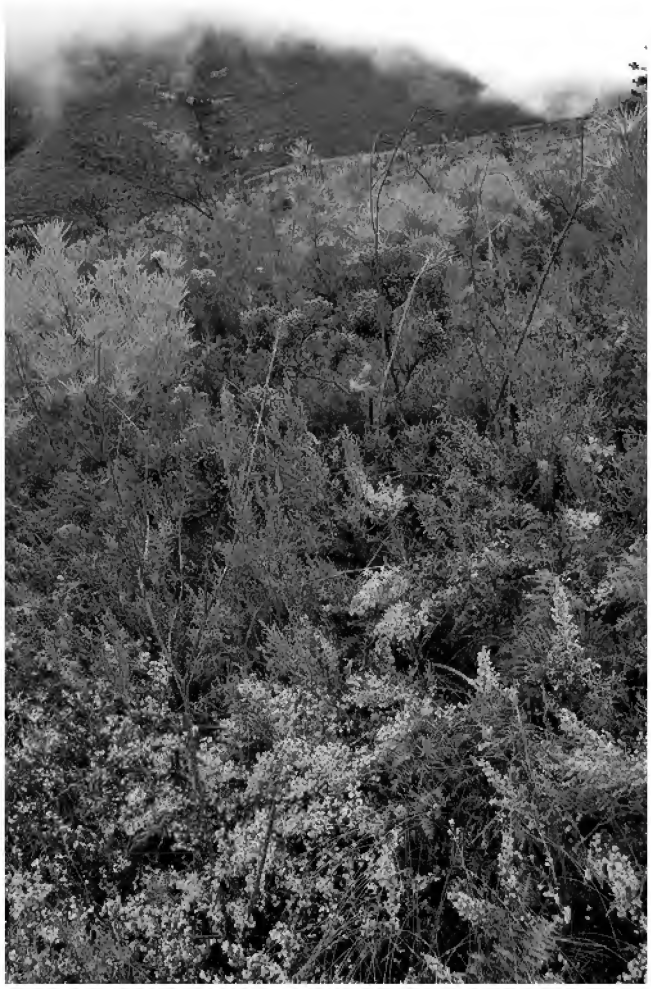

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Figure 4.38 FFs 16 South Langeberg Sandstone Fynbos: Proteoid fynbos with *Leucadendron eucalyptifolium* and *Erica melanthera* dominant in a seep on top of the Tradouw Pass in the Langeberg (Western Cape).

Geology & Soils Acidic lithosol soils derived from Ordovician sandstones of the Table Mountain Group (Cape Supergroup). Land types mainly Ib and Ic.

Climate MAP 320–1 440 mm (mean: 675 mm), peaking very slightly in winter and with a slight low from December to February. Southeasterly cloud brings heavy mist precipitation at higher altitudes in summer. Mean daily maximum and minimum temperatures 26.6°C and 4.0°C for January and July, respectively. Frost incidence 3–20 days per year. See also climate diagram for FFs 16 South Langeberg Sandstone Fynbos (Figure 4.21).

Important Taxa ([W]Wetlands) Small Trees: *Protea nitida* (d), *Widdringtonia nodiflora* (d). Tall Shrubs: *Cliffortia grandifolia* (d), *Leucadendron eucalyptifolium* (d), *Protea eximia* (d), *Psoralea pinnata*[W] (d), *Aspalathus willdenowiana*, *Euryops abrotanifolius*, *Leucospermum formosum*, *Podalyria calyptrata*. Low Shrubs: *Berzelia galpinii*[W] (d), *B. intermedia* (d), *Brunia alopecuroides*[W] (d), *Erica hispidula* (d), *E. longimontana* (d), *E. melanthera* (d), *Grubbia rosmarinifolia* (d), *Leucadendron salignum* (d), *L. spis-*

sifolium subsp. *spissifolium* (d), *Penaea cneorum* subsp. *ruscifolia* (d), *P. mucronata* (d), *Acmadenia matroosbergensis*, *A. tetragona*, *Anthospermum aethiopicum*, *Aspalathus angustifolia* subsp. *angustifolia*, *A. ciliaris*, *A. diffusa*, *A. grandiflora*, *A. inops*, *A. nigra*, *A. securifolia*, *A. stenophylla*, *A. vulpina*, *Asparagus rubicundus*, *Clutia laxa*, *Erica albens*, *E. cerinthoides* var. *cerinthoides*, *E. conferta*, *E. cordata*, *E. cubica*, *E. curviflora*[W], *E. cymosa* subsp. *grandiflora*, *E. daphniflora*, *E. glandulosa*, *E. multumbellifera*, *E. nematophylla*, *E. regerminans*, *E. tenuis*, *E. transparens*, *E. versicolor*, *E. vestita*, *Indigofera concava*, *Lachnaea penicillata*, *Leucadendron tinctum*, *Linconia alopecuroidea*, *Lobelia coronopifolia*, *Mimetes cucullatus*, *Paranomus candicans*, *Pelargonium candicans*, *Protea cynaroides*, *P. rupicola*, *P. speciosa*, *Raspalia virgata*, *Syncarpha eximia*, *S. vestita*, *Ursinia coronopifolia*[W], *U. hispida*, *U. scariosa* subsp. *subhirsuta*, *U. trifida*, *Zyrphelis microcephala*. Succulent Shrub: *Othonna quinquedentata*. Herbs: *Edmondia sesamoides* (d), *Carpacoce spermacocea*, *Chironia jasminoides*, *Helichrysum capense*, *H. crispum*, *Lobelia pubescens* var. *rotundifolia*, *Mairia hirsuta*, *Pseudoselago serrata*, *Senecio hastatus*. Geophytic Herbs: *Lanaria lanata* (d), *Blechnum tabulare*, *Geissorhiza burchellii*, *G. fourcadei*, *G. inconspicua*. Herbaceous Climber: *Cyphia zeyheriana*. Graminoids: *Anthochortus crinalis* (d), *Ehrharta dura* (d), *E. setacea* subsp. *scabra* (d), *Elegia asperiflora* (d), *E. filacea* (d), *E. juncea* (d), *Hypodiscus aristatus* (d), *Pentameris macrocalycina* (d), *Pentaschistis colorata* (d), *P. malouinensis* (d), *Platycaulos anceps* (d), *P. compressus* (d), *Restio inconspicuus* (d), *R. triticeus* (d), *Staberoha cernua* (d), *Tetraria bromoides* (d), *T. cuspidata* (d), *T. flexuosa* (d), *T. ustulata* (d), *Themeda triandra* (d), *Calopsis filiformis*, *Chrysitrix capensis*, *Cymbopogon marginatus*, *Elegia mucronata*, *E. stokoei*, *Eragrostis capensis*, *Hypodiscus montanus*, *Restio peculiaris*, *R. strictus*.

Endemic Taxa ([W]Wetlands) Tall Shrub: *Cliffortia densa*. Low Shrubs: *Erica blenna* var. *blenna* (d), *Spatalla parilis*[W] (d), *Acmadenia burchellii*, *Adenandra fragrans*, *Agathosma linifolia*, *A. subteretifolia*, *A. umbonata*, *Amphithalea bullata*, *A. dahlgrenii*, *Anderbergia elsiae*, *A. ustulata*, *A. vlokii*, *Anisothrix kuntzei*, *Aspalathus cordicarpa*, *A. hypnoides*, *A. shawii* subsp. *glabripetala*, *Athanasia inopinata*, *Berzelia burchellii*, *Carpacoce gigantea*, *Cliffortia lanceolata*, *Coleonema pulchrum*, *C. virgatum*, *Elytropappus* sp. nov. ('*monticola*'), *Empleurum fragrans*[W], *Erica albescens*, *E. amicorum*[W], *E. ardens*, *E. blenna* var. *grandiflora*, *E. bracteolaris*, *E. chartacea*, *E. comata*, *E. condensata*, *E. crassisepala*, *E. cubitans*, *E. dysantha*, *E. elsieana*, *E. garciae*, *E. grata*, *E. heleophila*, *E. inclusa*, *E. ixanthera*, *E. keeromsbergensis*, *E. macilenta*, *E. macrophylla*, *E. miniscula*, *E. obconica*, *E. ocellata*, *E. omninoglabra*, *E. oophylla*, *E. oxyandra*, *E. papyracea*, *E. parviporandra*, *E. podophylla*, *E. polifolia*, *E. procaviana*, *E. racemosa*, *E. stenantha*, *E. tetrathecoides*[W], *E. tradouwensis*, *E. vallisfluminis*, *E. winteri*, *Euchaetis avisylvana*, *Gymnostephium fruticosum*, *Helichrysum plebeium*, *Hippia hutchinsonii*, *Indigofera langebergensis*, *Kogelbergia phylicoides*, *Lachnaea ericoides*, *L. oliverorum*, *L. stokoei*, *Langebergia canescens*, *Lebeckia leptophylla*, *Leucadendron radiatum*, *L. tradouwense*, *Leucospermum winteri*, *Metalasia oligocephala*, *Mniothamnea bullata*, *M. callunoides*, *Muraltia langebergensis*, *Oedera laevis*, *Osteospermum burttianum*, *O. pyrifolium*, *Otholobium bowieanum*, *O. saxosum*, *Penaea dahlgrenii*, *Phylica lasiantha*, *P. longimontana*, *P. propinqua*, *P. recurvifolia*, *Raspalia barnardii*, *Spatalla colorata*, *S. nubicola*[W], *Stilbe gymnopharyngia*, *Stylapterus dubius*, *S. ericifolius*, *Thamnea gracilis*. Succulent Shrubs: *Drosanthemum acuminatum*, *D. subcompressum*, *Erepsia pentagona*, *Lampranthus hallii*, *L. laxifolius*. Semiparasitic Shrub: *Thesium susannae*. Herbs: *Aster bowiei*, *Galium undulatum*, *Lobelia dasyphylla*, *L. hypsibata*, *L. muscoides*, *Lyperia formosa*, *Mairia* sp. nov. ('*petiolaris*'), *Sebaea laxa*, *Sutera langebergensis*, *Wahlenbergia riversdalensis*, *Wimmerella longitubus*. Geophytic Herbs: *Bobartia macrospatha* subsp. *anceps*, *B. parva*, *Disa aurata*, *D. cardinalis*[W], *D. subtenuicornis*, *Geissoloma marginatum*, *Gladiolus crispulatus*, *Ixia stohriae*, *Lachenalia leomontana*, *Pachites appressa*. Graminoids: *Restio arcuatus* (d), *Calopsis monostylis*, *Ceratocaryum fistulosum*, *Ischyrolepis affinis*, *Restio fragilis*, *R. secundus*.

Conservation Least threatened. Target 30%. Statutorily conserved (23%) in the Marloth Nature Reserve and Boosmansbos Wilderness Area. An additional 54% enjoys protection in mountain catchment areas such as Langeberg-wes, Langeberg-oos and Matroosberg. Only 3% transformed (pine plantations, cultivation). Alien *Pinus pinaster*, *Hakea sericea* and *Acacia mearnsii* are found in places. Erosion very low and moderate.

Remark 1 Fire-safe kloofs support afrotemperate forest, with the westernmost extent of large forests at Grootvadersbos. There are indications that the MAP modelled in parts of this unit is an underestimate.

Remark 2 There are insufficient data to determine whether the Keerom Mountains (north and west of the Nuy Valley) should be grouped with FFs 8 South Hex Sandstone Fynbos or with this unit. Protea Atlas data suggest strong links to the Hex unit.

Remark 3 We have assumed that the eastern boundary of FFs 16 South Langeberg Sandstone Fynbos is at Cloete's Pass, based on FFs 15 North Langeberg Sandstone Fynbos. However, this assumption may not be valid, and more data are needed to determine an optimal boundary with FFs 19 South Outeniqua Sandstone Fynbos based on species distributions and associated vegetation patterns.

References Muir (1929), Kruger (1979), Rebelo et al. (1991), McDonald (1993a, b, c, 1995, 1999), McDonald et al. (1995, 1996).

FFs 17 Potberg Sandstone Fynbos

VT 47 Coastal Macchia (97%) (Acocks 1953). Mesic Mountain Fynbos (84%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (85%) (Low & Rebelo 1996). BHU 65 Potberg Mountain Fynbos Complex (84%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Mainly on the inselberg-like Potberg Mountain south of the lower Breede River to Melkhoutrivier, with an extension on to the flats towards Noetsie and an outlier on the coastal flats at Infanta. Altitude from the coast to 611 m on the highest peak of Potberg.

Vegetation & Landscape Features Prolonged, moderately steep sandstone coastal inselberg supporting moderately tall, dense restioid, ericoid-leaved and mainly proteoid shrublands. Proteoid and restioid fynbos predominate, other structural types are rare. Deeper kloofs support broad-leaved Cape thicket.

Geology & Soils Acidic lithosol soils derived from Ordovician sandstones of the Table Mountain Group (Cape Supergroup), Glenrosa and Mispah forms are prominent. Land types mainly Ic, Ib and Fb.

Climate MAP 410–550 mm (mean: 500 mm), fairly evenly throughout the year, but with a low from December to February. Mists covering the ridge are common in summer. Mean daily maximum and minimum temperatures 25.7°C and 6.1°C for January and July, respectively. Frost incidence 2 or 3 days per year. See also climate diagram for FFs 17 Potberg Sandstone Fynbos (Figure 4.21).

Important Taxa ([T]Cape thickets) Tall Shrubs: *Protea neriifolia* (d), *P. repens* (d), *Leucadendron eucalyptifolium* (d), *Aloe arborescens*[T], *Diospyros dichrophylla*[T], *Euclea polyandra*[T], *Euryops*

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Figure 4.39 FFs 17 Potberg Sandstone Fynbos: Proteoid fynbos with *Leucadendron xanthoconus* and *Protea neriifolia* on the slopes of the Potberg—a sandstone inselberg in the southeastern Overberg (Western Cape).

linearis, *Podalyria calyptrata*, *Psoralea aphylla*. Low Shrubs: *Leucadendron salignum* (d), *L. xanthoconus* (d), *Aspalathus aspalathoides*, *A. caledonensis*, *A. ciliaris*, *A. incurvifolia*, *Aulax umbellata*, *Erica coccinea* subsp. *uniflora*, *E. plukenetii* subsp. *bredensis*, *Indigofera angustifolia*, *Leucospermum calligerum*, *L. cuneiforme*, *L. utriculosum* (Potberg form), *Mimetes cucullatus*, *Nebelia paleacea*, *Oedera capensis*, *Paranomus abrotanifolius*, *Penaea mucronata*, *Phaenocoma prolifera*, *Polygala pottebergensis*, *Protea cynaroides*, *Roella incurva*, *Senecio paniculatus*, *Serruria acrocarpa*, *S. fasciflora*. Geophytic Herbs: *Acrolophia ustulata*, *Geissorhiza hispidula*, *Ornithogalum dubium*. Graminoids: *Ficinia zeyheri*, *Staberoha cernua*.

Endemic Taxa Tall Shrub: *Protea aurea* subsp. *potbergensis*. Low Shrubs: *Adenandra gummifera*, *Aspalathus potbergensis*, *Cliffortia incana*, *Muraltia pottebergensis*, *Prismatocarpus spinosus*, *Protea denticulata*, *Selago neglecta*. Herb: *Centella pottebergensis*. Geophytic Herb: *Bobartia longicyma* subsp. *microflora*.

Conservation Least threatened. Target 30%. Statutorily conserved (49%) in De Hoop Nature Reserve, with an additional 2% in the San Sebastian Private Nature Reserve. Only 5% transformed (cultivation). Aliens *Acacia cyclops* and *Eucalyptus* species occur in places. Erosion very low.

Remarks This is a very poorly explored unit from a vegetation-ecological point of view. Potberg Sandstone Fynbos has floristic links to both Langeberg (to the north), generally the higher altitude species, and to the Overberg sandstone mountains (to the west).

References C. Burgers (unpublished data), L. Mucina (unpublished data).

FFs 18 North Outeniqua Sandstone Fynbos

VT 70 False Macchia (67%), VT 43 Mountain Renosterbosveld (29%) (Acocks 1953). Dry Mountain Fynbos (48%), Mesic Mountain Fynbos (22%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (74%) (Low & Rebelo 1996). BHU 69 Outeniqua Mountain Fynbos Complex (71%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Northern slopes of the Outeniqua Mountains from the Cloetesberg northeast of Albertinia in the west to Vlug se Berg south of Uniondale in the east, and eastwards along the low range north of the N9 road. Altitude 300–1 579 m on Cradock's Berg north of George.

Vegetation & Landscape Features Gentle to steep north-facing slopes, with some intramontane valleys over a 135 km long area. Vegetation is a tall, open to medium dense shrubland with medium dense, medium tall shrub or restioid understorey with scattered, emergent, tall Proteaceae shrubs. Restioid and proteoid fynbos is the dominant vegetation-structural feature of the Outeniqua landscapes, with ericaceous and asteraceous fynbos becoming widespread at higher and lower altitudes, respectively. The lower boundary north of the N9 road becomes more arid as asteraceous fynbos approaches renosterveld. The old African surface conglomerates that occur on the northern slopes, especially west of Robinson Pass—and are mapped as part of this unit—are covered with *Dodonaea*-dominated asteraceous fynbos.

Geology & Soils Acidic lithosol soils (Glenrosa and Mispah forms prominent) derived from Ordovician sandstones of the

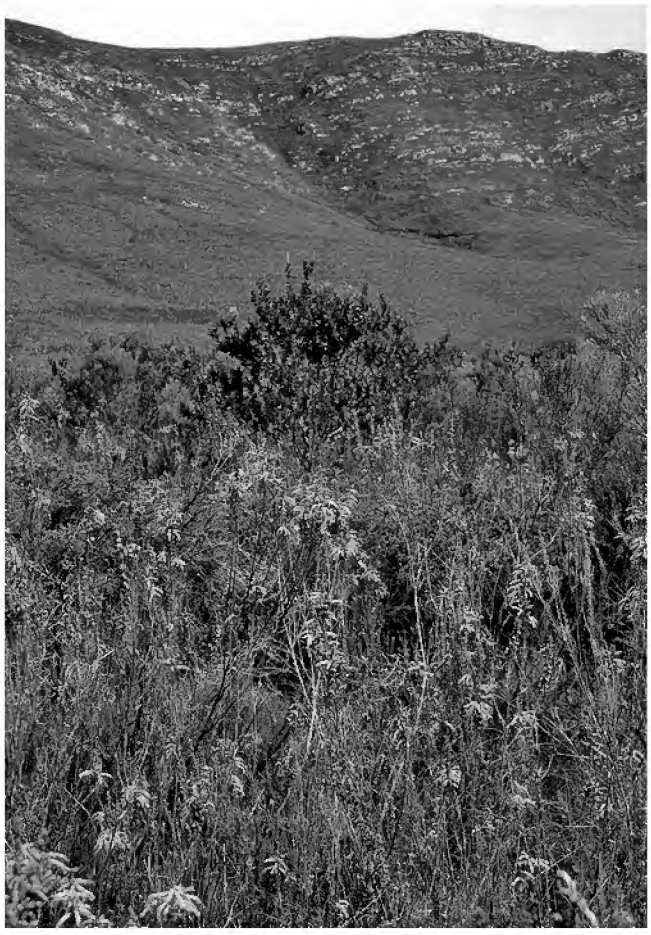

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Figure 4.40 FFs 18 North Outeniqua Sandstone Fynbos: Ericaceous fynbos with *Erica discolor* var. *hebecalyx* and proteoid fynbos (dominated by *Leucadendron salignum*) on the northern slopes of the Outeniqua Mountains, north of George (Western Cape).

Table Mountain Group (Cape Supergroup). Land types mainly Ib and Fc.

Climate MAP 240–950 mm (mean: 520 mm), evenly throughout the year. Mean daily maximum and minimum temperatures 29.2°C and 3.9°C for January and July, respectively. Frost incidence varies around 10 days per year. See also climate diagram for FFs 18 North Outeniqua Sandstone Fynbos (Figure 4.21).

Important Taxa ([W]Wetlands) Small Tree: *Protea nitida* (d). Tall Shrubs: *Aspalathus sceptrum-aureum*, *Chrysanthemoides monilifera*, *Leucadendron eucalyptifolium*, *Protea neriifolia*. Low Shrubs: *Erica brachycentra* (d), *Leucadendron salignum* (d), *Phylica axillaris* (d), *Acmadenia tetragona*, *Agathosma recurvifolia*, *Aspalathus granulata*, *Cliffortia ilicifolia*, *C. stricta, Diosma apetala*, *Elytropappus adpressus*, *E. gnaphaloides*, *Erica rosacea* subsp. *rosacea*, *E. uberiflora*, *Felicia filifolia* subsp. *filifolia*, *Leucospermum cuneiforme*, *Metalasia pulcherrima* f. *pallescens, Paranomus dispersus*, *Passerina obtusifolia*, *Stoebe capitata*, *Zygophyllum maculatum*. Geophytic Herbs: *Lanaria lanata* (d), *Geissorhiza roseoalba*, *Romulea jugicola*[W]. Graminoids: *Heteropogon contortus* (d), *Hypodiscus striatus* (d), *Pentaschistis eriostoma* (d), *Tetraria cuspidata* (d), *Aristida diffusa*, *Brachiaria serrata*, *Cannomois parviflora*, *Elegia galpinii*, *Mastersiella purpurea*, *Merxmuellera decora*, *Restio triticeus*, *Rhodocoma fruticosa*, *Themeda triandra*.

Endemic Taxa Tall Shrub: *Paranomus longicaulis*. Low Shrubs: *Aspalathus glabrescens*, *A. pedunculata*, *Erica croceovirens*, *E. inflaticalyx*, *E. solandra*, *E. zebrensis*, *Rafnia vlokii*. Geophytic Herb: *Oxalis attaquana*. Succulent Herb: *Haworthia outeniquensis*.

Conservation Least threatened. Target 23%. Statutorily conserved (11%) in the Doringrivier, Ruitersbos and Witfontein Nature Reserves. Some 14% transformed (cultivation). Alien *Hakea sericea* and *Pinus pinaster* scattered over part of the area. Erosion very low and low.

Remarks The western boundary of this unit is discussed under FFs 15 North Langeberg Sandstone Fynbos. The eastern boundary is also more of a transition zone and is somewhat arbitrary in its easternmost extremes. It could be located somewhere between Dieprivier (selected herein) and Prince Alfred's Pass, and can be refined only when sufficient distributional data become available.

Reference Bond (1981).

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Figure 4.41 FFs 19 South Outeniqua Sandstone Fynbos: Slopes of deep valleys north of George clad in dense species-rich ericaceous fynbos and remnants of afrotemperate forests on the Outeniqua Mountains, north of George (Western Cape).

FFs 19 South Outeniqua Sandstone Fynbos

VT 4 Knysna Forest (80%), VT 70 False Macchia (18%) (Acocks 1953). Wet Mountain Fynbos (48%), Mesic Mountain Fynbos (32%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (78%) (Low & Rebelo 1996). BHU 69 Outeniqua Mountain Fynbos Complex (54%), BHU 71 Tsitsikamma Mountain Fynbos Complex (23%), BHU 100 Knysna Afromontane Forest (17%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Southern slopes of the Outeniqua Mountains from the Cloetesberg northeast of Albertinia in the west to the upper reaches of the Keurbooms River where it borders on FFs 20 Tsitsikamma Sandstone Fynbos. It includes sandstone outcrops on the lowlands from the vicinity of the Goukamma River near Knysna in the west and Komkromma Point near Nature's Valley in the east. Altitude from the coast to 1 579 m on Cradock's Berg north of George.

Vegetation & Landscape Features Gentle to steep south-facing slopes, over a 160 km long area, relatively broad with some moderately sloping intramontane valleys in the west where it is over 10 km wide. The dominant vegetation is a tall, open to medium dense shrubland with medium dense, medium tall shrub understorey—mainly proteoid and restioid fynbos, with extensive ericaceous fynbos on the upper slopes. Some grassy fynbos at lower altitudes, and scrub fynbos in riverine areas. Patches of this unit are not confined to south-facing slopes, but are found on all slopes south of the highest peaks in the range. Thus there are extensive northern slopes in some intramontane valley systems, the most significant of those found in the Doring River Wilderness Area.

Geology & Soils Acidic lithosol soils derived from Ordovician sandstones of the Table Mountain Group (Cape Supergroup). Land types mainly Ib, Gb and Fa.

Climate MAP 360–1 170 mm (mean: 785 mm), with a slight bimodal winter and a low in December. Mean daily maximum and minimum temperatures 27.8°C and 4.8°C for January and July, respectively. Frost incidence 2–10 days per year. See also climate diagram for FFs 19 South Outeniqua Sandstone Fynbos (Figure 4.21).

Important Taxa ([T]Cape thickets, [W]Wetlands) Small Tree: *Widdringtonia nodiflora*. Tall Shrubs: *Chrysanthemoides monilifera* (d), *Laurophyllus capensis*[T] (d), *Leucadendron conicum* (d), *L. eucalyptifolium* (d), *L. uliginosum* subsp. *uliginosum* (d), *Metalasia densa* (d), *Protea neriifolia* (d), *P. repens* (d), *Anginon difforme*, *Dodonaea viscosa* var. *angustifolia*, *Halleria lucida*[T], *Leucospermum glabrum*, *Liparia hirsuta*, *Metalasia trivialis*, *Mimetes pauciflorus*, *Osteospermum junceum*, *Passerina falcifolia*, *Podalyria burchellii*, *P. sericea*, *Protea mundii*, *Psoralea affinis*, *Pterocelastrus tricuspidatus*[T]. Low Shrubs: *Berzelia intermedia* (d), *Brunia nodiflora* (d), *Erica cordata* (d), *E. densifolia* (d), *E. glomiflora* (d), *E. triceps* (d), *E. uberiflora* (d), *Leucadendron ericifolium* (d), *Penaea cneorum* subsp. *cneorum* (d), *P. cneorum* subsp. *gigantea* (d), *Acmadenia maculata*, *A. tetragona*, *Anisodontea scabrosa*, *Aspalathus angustifolia* subsp. *angustifolia*, *A. ciliaris*, *A. rubens*, *Cliffortia ilicifolia*, *C. stricta*, *Erica deflexa*, *E. dis-*

color variant '*speciosa*', *E. formosa*, *E. fuscescens*, *E. gracilis*, *E. hispidula*, *E. lanata*, *E. nabea*, *E. similis*, *E. simulans*, *E. sparsa*, *E. versicolor*, *Euryops pinnatipartitus*, *Lachnaea diosmoides*, *Leucadendron comosum* subsp. *comosum*, *L. salignum*, *L. spissifolium* subsp. *fragrans*, *Leucospermum cuneiforme*, *L. wittebergense*, *Linconia alopecuroidea*, *Lobelia neglecta*, *Mimetes cucullatus*, *Otholobium carneum*, *Phaenocoma prolifera*, *Phylica confusa*, *Protea cynaroides*, *P. lorifolia*, *Pseudobaeckea cordata*, *Relhania calycina*, *Senecio glastifolius*, *Stoebe alopecuroides*, *Struthiola eckloniana*, *Syncarpha paniculata*, *Ursinia coronopifolia*, *U. scariosa* subsp. *scariosa*, *U. trifida*. Semiparasitic Shrub: *Thesium virgatum*. Herbs: *Carpacoce spermacocea*, *Centella affinis*, *C. virgata*, *Dichrocephala integrifolia* subsp. *integrifolia*, *Helichrysum felinum*, *Mairia crenata*. Geophytic Herbs: *Pteridium aquilinum* (d), *Blechnum attenuatum*, *Caesia contorta*, *Geissorhiza bracteata*, *G. fourcadei*, *G. inconspicua*, *Lanaria lanata*, *Romulea fibrosa*, *Tritoniopsis caffra*, *Watsonia fourcadei*. Carnivorous Herb: *Drosera trinervia*[W]. Herbaceous Parasitic Climber: *Cassytha ciliolata*. Graminoids: *Cannomois parviflora* (d), *C. virgata* (d), *Ehrharta dura* (d), *E. rupestris* subsp. *tricostata* (d), *Elegia fistulosa* (d), *E. galpinii* (d), *E. juncea* (d), *Epischoenus adnatus* (d), *Hypodiscus albo-aristatus* (d), *H. aristatus* (d), *H. striatus* (d), *H. synchroolepis* (d), *Ischyrolepis gaudichaudiana* (d), *Merxmuellera rufa* (d), *Pentameris distichophylla* (d), *Platycaulos anceps* (d), *P. compressus* (d), *Restio fourcadei* (d), *R. triticeus* (d), *Rhodocoma gigantea*[W] (d), *Tetraria cuspidata* (d), *T. involucrata* (d), *T. microstachys* (d), *Andropogon appendiculatus*, *Anthochortus ecklonii*, *Cannomois scirpoides*, *Capeobolus brevicaulis*, *Chrysitrix capensis*, *Cyathocoma hexandra*[W], *Ficinia gracilis*, *Mastersiella purpurea*, *Merxmuellera decora*, *Pentaschistis colorata*, *P. malouinensis*, *P. pallida*, *Restio strictus*, *Staberoha aemula*, *Tetraria capillacea*, *T. fimbriolata*, *T. sylvatica*, *T. thermalis*, *T. ustulata*, *Thamnochortus cinereus*, *Themeda triandra*, *Willdenowia teres*.

Endemic Taxa ([W]Wetlands) Low Shrubs: *Erica unicolor* (d), *Penaea acutifolia* (d), *Acmadenia gracilis*, *A. rupicola*, *Agathosma alaris*, *A. planifolia*, *Amphithalea flava*, *Aspalathus bowieana*, *A. digitifolia*, *Erica aneimena*, *E. gillii*, *E. inconstans*, *E. juniperina*, *E. lehmannii*, *E. outeniquae*, *E. priorii*, *E. velatiflora*, *Leucadendron olens*, *Leucospermum hamatum*, *Phylica curvifolia*, *Prismatocarpus rogersii*, *Psoralea vlokii*, *Xiphotheca phylicoides*, *Zyrphelis outeniquae*. Succulent Shrub: *Lampranthus pauciflorus*. Herb: *Linum villosum*. Geophytic Herb: *Geissorhiza outeniquensis*[W].

Conservation Vulnerable. Target 23%. Statutorily conserved (47%) in the proposed Garden Route National Park, Doring River Wilderness Area as well as in Ruitersbos and Witfontein Nature Reserves. About 2% protected in private nature reserves. Some 28% transformed (pine plantations, cultivation). Alien *Pinus pinaster* and *Hakea sericea* scattered over part of the area. Erosion very low.

Remarks The western boundaries of this unit are discussed under FFs 16 South Langeberg Sandstone Fynbos. The Cedarberg Shale Bands were not adequately mapped within this unit due to a lack of proper geological coverage. The eastern boundary is also more of a transition zone and is somewhat arbitrarily taken as approximating the Keurbooms River (for the mountain section). It can be refined when sufficient distributional data become available.

References Bond (1978b, 1981), Cameron (1980), Van Daalen (1984), Vermeulen (1995).

FFs 20 Tsitsikamma Sandstone Fynbos

VT 4 Knysna Forest (58%), VT 70 False Macchia (42%) (Acocks 1953). Wet Mountain Fynbos (33%), Mesic Mountain Fynbos (21%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (54%) (Low & Rebelo 1996). BHU 71 Tsitsikamma Mountain Fynbos Complex (49%), BHU 100 Knysna Afromontane Forest (19%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western and Eastern Cape Provinces: Tsitsikamma Mountains from Uniondale to Cape St Francis, north of the Keurbooms River and south of Langkloof. Altitude 100–1 675 m (at the highest Peak Formosa).

Vegetation & Landscape Features A relatively low mountain range with gentle to steep both northern and southern slopes over 140 km, with a few high peaks and moderately undulating plains. Relatively broad compared to the other coastal mountain ranges varying from 10–20 km in width. Vegetation is a medium dense, tall proteoid shrubland over a dense moderately tall, ericoid-leaved shrubland—mainly proteoid, restioid and ericoid fynbos, with fynbos thicket in wetter areas.

Geology & Soils Acidic lithosol soils derived from Ordovician sandstones of the Table Mountain Group (Cape Supergroup), plinthic catenas prominent. Land types mainly Ib, Ca and Bb.

Climate MAP 480–1 230 mm (mean: 845 mm), fairly even throughout the year. Mean daily maximum and minimum temperatures 25.5°C and 5.8°C for February and July, respectively. Frost incidence 2–10 days per year. See also climate diagram for FFs 20 Tsitsikamma Sandstone Fynbos (Figure 4.21).

Important Taxa ([T]Cape thickets) Tall Shrubs: *Cliffortia serpyllifolia* (d), *Leucadendron conicum* (d), *L. eucalyptifolium* (d), *L. uliginosum* subsp. *glabratum*, *Leucospermum glabrum*, *Metalasia densa*, *M. trivialis*, *Mimetes pauciflorus*, *Passerina corymbosa*, *P. falcifolia*, *Protea eximia*, *P. mundii*, *P. neriifolia*,

L. Mucina

Figure 4.42 FFs 20 Tsitsikamma Sandstone Fynbos: Wet proteoid fynbos with dominant *Leucadendron* and abundant *Erica* on the south-facing slopes of the Tsitsikamma Mountains.

Pterocelastrus tricuspidatus[T]. Low Shrubs: *Erica discolor* variant '*speciosa*' (d), *E. sparsa* (d), *Ursinia scariosa* subsp. *scariosa* (d), *Agathosma ovata*, *Anisodontea scabrosa*, *Aspalathus ciliaris*, *Berzelia intermedia*, *Carpacoce vaginellata*, *Erica diaphana*, *E. glandulosa*, *E. rosacea* subsp. *rosacea*, *E. uberiflora*, *Euryops munitus*, *E. pinnatipartitus*, *Helichrysum teretifolium*, *Indigofera flabellata*, *Leucadendron salignum*, *L. spissifolium* subsp. *phillipsii*, *Leucospermum cuneiforme*, *Metalasia pulcherrima* f. *pallescens*, *Otholobium carneum*, *Passerina pendula*, *Penaea cneorum* subsp. *gigantea*, *Phylica axillaris*, *P. imberbis*, *Protea cynaroides*, *Stoebe plumosa*. Herbs: *Commelina africana*, *Gazania krebsiana* subsp. *krebsiana*. Geophytic Herbs: *Geissorhiza fourcadei*, *G. inconspicua*, *Romulea pratensis*. Graminoids: *Restio triticeus* (d), *Tetraria capillacea* (d), *Diheteropogon filifolius*, *Elegia juncea*, *Epischoenus adnatus*, *Heteropogon contortus*, *Hypodiscus synchroolepis*, *Tetraria robusta*, *Thamnochortus fruticosus*, *T. glaber*, *Themeda triandra*, *Tristachya leucothrix*.

Endemic Taxa Low Shrubs: *Aspalathus teres* subsp. *thodei*, *Erica trachysantha*, *E. zitzikammensis*, *Felicia tsitsikamae*, *Helichrysum outeniquense*.

Conservation Vulnerable. Target 23%. Statutorily conserved (about 40%) in the proposed Garden Route National Park (including Tsitsikamma and Soetkraal). Some 33% transformed (cultivation, pine plantations). With scattered alien *Pinus pinaster* and *Hakea sericea*. Erosion very low.

Remark 1 Wetter habitats, especially in berg wind shadows east of dissected valleys, support afrotemperate forests. Most of the bigger patches of the forest are positioned on and around the shales of the Gydo Formation.

Remark 2 The coastal strip contains a narrow shoreward band of dune fynbos communities that were not mapped, but included within this unit.

References Bond (1978a), Cowling (1984), Bond et al. (1988), Hanekom et al. (1989).

FFs 21 North Rooiberg Sandstone Fynbos

VT 70 False Macchia (73%), VT 25 Succulent Mountain Scrub (Spekboomveld) (27%) (Acocks 1953). Dry Mountain Fynbos (84%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (92%) (Low & Rebelo 1996). BHU 67 Rooiberg Mountain Fynbos Complex (95%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Northern slopes of the mountains of Rooiberg, Gamka and the Amalienstein Ridge-Sandberg-Bakenkop range. Altitude 500–1 490 m on the summit of Rooiberg.

Vegetation & Landscape Features Systems of gentle to steep north-facing slopes, deeply dissected in parts. The Cedarberg Shale Band is prominent in parts. Vegetation is mainly asteraceous (lowest slopes), proteoid and restioid fynbos. Proteoid overstorey often found over restioid shrubland.

Geology & Soils Acidic lithosol soils derived from Ordovician sandstones of the Table Mountain Group (Cape Supergroup). Land types mainly Ic.

Climate MAP 160–710 mm (mean: 330 mm), with no prominent peak, but a low from December to February. Mean daily maximum and minimum temperatures 29.7°C and 3.0°C for January and July, respectively. Frost incidence 10–20 days per year. See also climate diagram for FFs 21 North Rooiberg Sandstone Fynbos (Figure 4.21).

Important Taxa ([T]Cape thickets) Small Tree: *Protea nitida* (d). Tall Shrubs: *Passerina corymbosa* (d), *Protea repens* (d), *Diospyros dichrophylla*[T], *Leucadendron rubrum*, *Leucospermum pluridens*, *Protea eximia*. Low Shrubs: *Agathosma ovalifolia* (d), *Elytropappus rhinocerotis* (d), *Leucadendron salignum* (d), *Phylica purpurea* (d), *Protea lorifolia* (d), *Syncarpha paniculata* (d), *Anthospermum aethiopicum*, *Aspalathus granulata*, *A. rubens*, *Cullumia bisulca*, *Dolichothrix ericoides*, *Elytropappus glandulosus*, *Euryops erectus*, *Felicia filifolia* subsp. *filifolia*, *Leucospermum wittebergense*, *Lobelia coronopifolia*, *Metalasia pallida*, *Oedera squarrosa*, *Paranomus dispersus*, *Pelargonium tricolor*, *Phylica rigidifolia*, *Struthiola martiana*, *Ursinia heterodonta*, *Wahlenbergia neorigida*. Herbs: *Centella virgata* (d), *Gazania linearis*. Geophytic Herb: *Geissorhiza roseoalba*. Graminoids: *Ehrharta ramosa* subsp. *aphylla* (d), *Hypodiscus striatus* (d), *Ischyrolepis capensis* (d), *Mastersiella purpurea* (d), *Merxmuellera arundinacea* (d), *Pentaschistis eriostoma* (d), *Rhodocoma fruticosa* (d), *Tetraria ustulata* (d), *Thamnochortus cinereus* (d), *Ehrharta calycina*, *Elegia galpinii*, *Pentaschistis colorata*, *Tetraria exilis*.

Endemic Taxa Tall Shrubs: *Freylinia vlokii*, *Paranomus roodebergensis*. Low Shrub: *Lotononis dahlgrenii*.

Conservation Least Threatened. Target 27%. Statutorily conserved (33%) in the Gamkaberg, Groenefontein and Rooiberg Nature Reserves, with an additional 25% protected in Rooiberg Mountain Catchment Area. No transformation recorded and aliens *Pinus halepensis* and *Hakea sericea* are rare. Erosion very low and low.

Remarks Arid lower slopes at the bottom margin of fynbos give way to karoo shrublands and spekboomveld, the boundary being a fire-maintained mosaic of fynbos with karoo shrubland in the more fire-protected areas. Deep kloofs have a thicket with *Buddleja saligna* as well as various species of *Pelargonium* and *Salvia*.

References Taylor (1979), Taylor & Van der Meulen (1981).

FFs 22 South Rooiberg Sandstone Fynbos

VT 70 False Macchia (64%), VT 25 Succulent Mountain Scrub (Spekboomveld) (33%) (Acocks 1953). Dry Mountain Fynbos (66%), Mesic Mountain Fynbos (28%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (95%) (Low & Rebelo 1996). BHU 67 Rooiberg Mountain Fynbos Complex (93%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Southern slopes of the mountains of Rooiberg, Gamka and the Amalienstein Ridge-Sandberg-Bakenskop range. Altitude 350–1 490 m on the summit of Rooiberg.

Vegetation & Landscape Features Steep to gentle south-facing slopes, deeply dissected in a few places. Ericaceous fynbos found at high altitudes, with proteoid and restioid fynbos at middle levels, and waboomveld and asteraceous fynbos at the lowest altitudes within the unit. The lower edge with a tendency to patches of restioid fynbos within asteraceous fynbos, being too dry in the central and eastern sections to support proteoid fynbos.

Geology & Soils Acidic lithosol soils derived from Ordovician sandstones of the Table Mountain Group (Cape Supergroup). Land types mainly Ib and Ic.

Climate MAP 250–710 mm (mean: 465 mm), fairly even but with a low from December to February. Mean daily maximum and minimum temperatures 29.4°C and 3.5°C for January and July, respectively. Frost incidence 10–20 days per year. See also climate diagram for FFs 22 South Rooiberg Sandstone Fynbos (Figure 4.21).

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Figure 4.43 FFs 22 South Rooiberg Sandstone Fynbos: Proteoid fynbos dominated by *Leucadendron salignum* in the Rooiberg Mountains near Ladismith (Western Cape).

Important Taxa ([W]Wetlands) Small Tree: *Protea nitida* (d). Tall Shrubs: *Leucadendron eucalyptifolium* (d), *Protea eximia* (d), *P. neriifolia* (d), *P. punctata* (d), *P. repens* (d), *Psoralea pinnata*[W] (d). Low Shrubs: *Berzelia intermedia* (d), *Elytropappus glandulosus* (d), *Erica hispidula* (d), *Leucadendron comosum* subsp. *comosum* (d), *L. salignum* (d), *Protea lorifolia* (d), *Anthospermum galioides* subsp. *galioides*, *Leucospermum wittebergense*, *Mimetes chrysanthus*, *Paranomus dispersus*, *Wahlenbergia neorigida*. Herb: *Sutera subnuda*. Geophytic Herbs: *Geissorhiza delicatula*, *Romulea fibrosa*. Graminoids: *Cannomois virgata* (d), *Elegia juncea* (d), *Mastersiella purpurea* (d), *Merxmuellera arundinacea* (d), *Tetraria ustulata* (d), *Cymbopogon marginatus*, *Ficinia deusta*, *Pentaschistis eriostoma*, *Themeda triandra*.

Endemic Taxa Low Shrubs: *Anderbergia rooibergensis*, *Argyrolobium rarum*, *Aspalathus karrooensis*, *Asparagus oliveri*, *Cliffortia concinna*, *Metalasia tricolor*, *Selago rubromontana*.

Conservation Least Threatened. Target 27%. Statutorily conserved (34%) in the Rooiberg Nature Reserve, with an additional 10% protected in the Rooiberg Mountain catchment area. Only very little transformed. The alien tree *Pinus halepensis* occurs, but is generally rare. Erosion generally low.

Remarks Vegetation data are from a provisional and structural survey addressing the westernmost regions of the unit. No data exist for the eastern section, which contains the Gamka Nature Reserve. South Rooiberg Sandstone Fynbos forms a partial corridor between fynbos types at a similar aspect on the Swartberg and Langeberg Mountains, and this probably partly accounts for the higher richness of the Klein Swartberg compared to the Groot Swartberg (A.G. Rebelo unpublished data).

References Taylor (1979), Taylor & Van der Meulen (1981).

FFs 23 North Swartberg Sandstone Fynbos

VT 70 False Macchia (83%) (Acocks 1953). Dry Mountain Fynbos (26%), Mesic Mountain Fynbos (20%), South Coast Renosterveld (16%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (79%) (Low & Rebelo 1996). BHU 68 Groot Swartberg Mountain Fynbos Complex (51%), BHU 66 Klein Swartberg Mountain Fynbos Complex (32%) (Cowling et al. 1999b, Cowling & Heijnis 2001). Anysberg Arid Fynbos, Anysberg Grassy Fynbos, Anysberg Proteoid Fynbos p.p. (Vlok 2002).

Distribution Western and Eastern Cape Provinces: Stretching 270 km along the northern slopes of the Anysberg, Klein and Groot Swartberg to Slypsteenberg and Resbosrand in the east. Also includes the northern slope of the Touwsberg. Altitude 700–1 800 m. Peaks higher than 1 800 m constitute FFs 31 Swartberg Altimontane Sandstone Fynbos.

Vegetation & Landscape Features Steep to very steep, mostly north-facing slopes, deeply dissected in parts. East-west-trending rugged mountain ranges. Structurally this is mainly asteraceous, proteoid and restioid fynbos; graminoid fynbos rare.

Geology & Soils Acidic lithosol soils derived from Ordovician sandstones of the Table Mountain Group (Cape Supergroup). Land types mainly Ic and Ib.

Climate MAP 160–580 mm (mean: 375 mm), peaking slightly in March, but otherwise even with a low from December to February. Mean daily maximum and minimum temperatures 28.3°C and 1.6°C for January and July, respectively. Frost incidence 10–40 days per year. See also climate diagram for FFs 23 North Swartberg Sandstone Fynbos (Figure 4.21).

Important Taxa Small Tree: *Protea nitida*. Tall Shrubs: *Protea repens* (d), *Aspalathus hystrix*, *A. sceptrum-aureum*, *Leucadendron rubrum*, *Protea eximia*, *P. punctata*. Low Shrubs: *Protea lorifolia* (d), *Acmadenia sheilae*, *Agathosma capensis*, *A. mundtii*, *Anthospermum galioides* subsp. *galioides*, *A. spathulatum* subsp. *spathulatum*, *Cliffortia setifolia*, *Elytropappus* sp. nov. ('*aridus*'), *Erica rosacea* subsp. *glabrata*,

L. Mucina

Figure 4.44 FFs 23 North Swartberg Sandstone Fynbos: Proteoid fynbos with *Protea eximia* against the backdrop of *Leucadendron*-clad north-facing slopes of the Swartberg Pass, Klein Swartberg Mountains (Western Cape).

E. strigilifolia, *E. zwartbergensis*, *Euryops bolusii*, *E. erectus*, *E. glutinosus*, *Felicia filifolia* subsp. *filifolia*, *Leucadendron salignum*, *Leucospermum wittebergense*, *Metalasia pallida*, *M. pungens*, *Paranomus centaureoides*, *P. dregei*, *Passerina obtusifolia*, *Protea canaliculata*. Graminoids: *Restio triticeus* (d), *Rhodocoma fruticosa* (d), *Tetraria ustulata* (d), *Cannomois scirpoides*, *Cymbopogon marginatus*, *Ehrharta calycina*, *Hypodiscus striatus*, *Ischyrolepis hystrix*, *Pentaschistis eriostoma*, *Themeda triandra*, *Willdenowia teres*.

Endemic Taxa Low Shrubs: *Acmadenia fruticosa*, *Aspalathus lamarckiana*, *Cliffortia nivenioides*, *Erica insignis*, *Indigofera thesioides*. Succulent Shrub: *Lampranthus pocockiae*. Succulent Herb: *Haworthia vlokii*.

Conservation Least threatened. Target 27%. Statutorily conserved (70%) in the Groot Swartberg, Towerkop, Anysberg and Swartberg East Nature Reserves, with an additional 5% protected in private conservation areas such as Klein Swartberg. Only 2% transformed (cultivation). Alien woody plants include *Pinus pinaster* and *P. radiata*. Erosion very low.

Remark 1 At very low rainfall conditions (< 300 mm) at lower altitudes, asteraceous fynbos is replaced by a grassy shrubland—a thicket type—in a wide transition zone. Deep fire-protected kloofs have thickets with *Buddleja saligna*, and species of *Pelargonium* and *Salvia*.

Remark 2 Despite the prominence and importance of especially the Swartberg, this is a poorly known vegetation unit.

References Bond (1981), Vlok (2002).

FFs 24 South Swartberg Sandstone Fynbos

VT 70 False Macchia (83%) (Acocks 1953). Mesic Mountain Fynbos (65%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (87%) (Low & Rebelo 1996). BHU 68 Groot Swartberg Mountain Fynbos Complex (49%), BHU 66 Klein Swartberg Mountain Fynbos Complex (36%) (Cowling et al. 1999b, Cowling & Heijnis 2001). Anysberg Wet Fynbos, Anysberg Proteoid Fynbos p.p. (Vlok 2002).

Distribution Western and Eastern Cape Provinces: Southern slopes of the Anysberg, Klein and Groot Swartberg to Slypsteenberg and Resbosrand in the east. Also includes the southern slope of the Touwsberg. Altitude 550 m to the lower boundary of the FFs 31 Swartberg Altimontane Sandstone Fynbos at about 1 800 m.

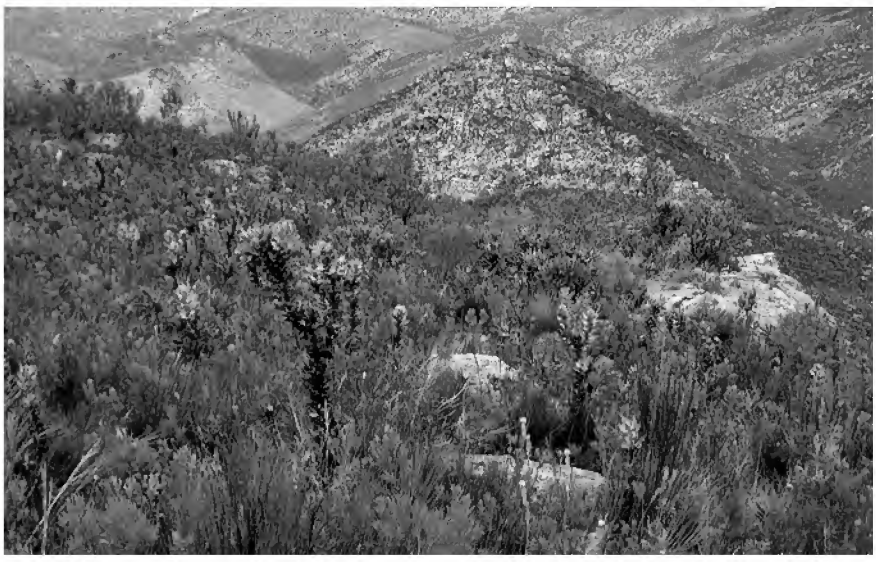
Vegetation & Landscape Features Steep, very steep, and precipitous south-facing slopes, deeply dissected in parts, of rugged mountain ranges. Vegetation is a medium tall shrubland and heathland. Proteoid and restioid fynbos dominate, with ericaceous fynbos at higher altitudes and scrub fynbos at lower altitudes.

Geology & Soils Acidic lithosol soils derived from Ordovician sandstones of the Table Mountain Group (Cape Supergroup). Land types mainly Ib and Ic.

Climate MAP 170–850 mm (mean: 475 mm), peaking slightly in March, but otherwise even with a low from December to February. Mean daily maximum and minimum temperatures 28.5°C and 2.0°C for January and July, respectively. Frost incidence 10–30 days per year. See also climate diagram for FFs 24 South Swartberg Sandstone Fynbos (Figure 4.21).

Important Taxa Small Tree: *Protea nitida*. Tall Shrubs: *Phylica paniculata* (d), *Protea eximia* (d), *P. punctata* (d), *P. repens* (d), *Euryops tenuissimus* subsp. *tenuissimus*, *E. virgineus*, *Leucadendron eucalyptifolium*, *L. rubrum*, *Metalasia densa*. Low Shrubs: *Erica andreaei* (d), *E. fimbriata* (d), *E. petraea* (d), *Leucadendron album* (d), *L. comosum* subsp. *comosum* (d), *Agathosma capensis*, *A. mundtii*, *Anthospermum aethiopicum*, *Aspalathus congesta*, *A. pachyloba* subsp. *villicaulis*, *A. patens*, *Brunia nodiflora*, *Cliffortia robusta*, *C. setifolia*, *C. tuberculata*, *Cyclopia burtonii*, *Disparago ericoides*, *Erica discolor* variant '*speciosa*', *E. esterhuyseniae*, *E. hispidula*, *E. melanthera*, *E. nervata*, *E. strigilifolia*, *E. tenuis*, *E. uberiflora*, *E. umbelliflora*, *E. zwartbergensis*, *Euryops bolusii*, *E. rehmannii*, *Heliophila rimicola*, *Leucadendron barkerae*, *L. dregei*, *L. salignum*, *L. spissifolium* subsp. *fragrans*, *Leucospermum cuneiforme*, *L. wittebergense*, *Metalasia strictifolia*, *Otholobium swartbergense*, *Paranomus centaureoides*, *Passerina obtusifolia*, *Pelargonium ovale*, *Protea intonsa*, *P. lorifolia*, *P. montana*, *P. venusta*, *Stoebe cinerea*, *Syncarpha paniculata*, *Ursinia scariosa* subsp. *scariosa*. Succulent Shrub: *Crassula obtusa*. Geophytic Herbs: *Cheilanthes eckloniana*, *Geissorhiza delicatula*, *Moraea monticola*. Graminoids: *Cannomois scirpoides* (d), *Cymbopogon pospischilii* (d), *Hypodiscus striatus* (d), *Ischyrolepis distracta* (d), *Merxmuellera stricta* (d), *Restio triticeus* (d), *Tetraria cuspidata* (d), *T. ustulata* (d), *Willdenowia teres* (d), *Brachiaria serrata*, *Hypodiscus aboaristatus*, *H. synchroolepis*, *Rhodocoma fruticosa*, *Tetraria involucrata*, *Themeda triandra*.

Endemic Taxa ([W]Wetlands) Tall Shrubs: *Cliffortia conifera*, *Hymenolepis cynopus*, *Liparia racemosa*, *Protea aristata*, *Stirtonanthus chrysanthus*, *S. taylorianus*. Low Shrubs: *Adenandra dahlgrenii*, *Agathosma purpurea*, *Anderbergia epaleata*, *Anisothrix integra*, *Aspalathus ramosissima*, *Cliffortia aculeata*, *C. cervicornu*, *C. crassinervis*, *C. montana*, *C. verrucosa*, *Erica astroites*[W], *E. atromontana*, *E. chionodes*[W], *E. jananthus*, *E. kirstenii*, *E. phaeocarpa*, *E. umbratica*, *E. viridiflora* subsp. *redacta*, *Helichrysum saxicola*, *Leucospermum secundifolium*, *Liparia confusa*, *Muraltia carnosa*, *M. elsieae*, *Nivenia parviflora*, *N. stenosiphon*, *Otholobium rubicundum*, *Phylica costata*, *P. nigromontana*, *P. sericea*, *P.*



D. Gwynne-Evans

Figure 4.45 FFs 24 South Swartberg Sandstone Fynbos: Proteoid fynbos on southern slopes of the Touwsberg (Western Cape) with *Protea eximia*, *Leucadendron eucalyptifolium* and *Hypocalyptus oxalidifolia*.

stokoei, *Phymaspermum appressum, Selago adenodes*, *S. exigua*, *S. oppositifolia*. Succulent Shrubs: *Lampranthus affinis*, *Sceletium strictum*. Herbs: *Berkheya francisci*, *Heliophila ephemera*, *Lobelia eurypoda* var. *fissurarum*, *Osteospermum asperulum*, *Sutera tenuicaulis*. Geophytic Herbs: *Geissorhiza nigromontana*[W], *G. uliginosa*[W], *Gladiolus aquamontanus*, *G. nigromontanus*, *Moraea exiliflora*. Succulent Herb: *Crassula peculiaris*. Graminoids: *Ficinia petrophila*, *Restio rarus*.

Conservation Least threatened. Target 27%. Some 47% statutorily conserved in the Groot Swartberg, Swartberg East and Anysberg Nature Reserves, with an additional 35% conserved in mountain catchment areas (Klein Swartberg, Groot Swartberg, Swartberg-oos). Only very small portion has been transformed. Alien woody species worth mentioning are *Pinus pinaster* and *P. radiata*. Erosion very low.

Remarks The Klein Swartberg portion deserves to be recognised as a centre of endemism in its own right and should perhaps have been separated as a unit herein. However, at this stage it is not clear how much of this is an effect of altitude, since many near-endemics to this portion have been found at higher peaks to the east, most notably Blesberg (including FFs 31 Swartberg Altimontane Sandstone Fynbos). The logical boundary (based on Proteaceae) is the Gamka River gap. In the west there appear to be few species confined to Anysberg, with one confined to Touwsberg. In the east Antoniesberg shares marginally more species with FFs 28 Kouga Grassy Sandstone Fynbos than with Swartberg and has been linked with the former, although the eastern Groot Swartberg also tends to share many species with the Kouga Mountains.

References Bond (1981), Vlok (2002), C. Boucher (unpublished data), Protea Atlas Project (unpublished data).

FFs 25 North Kammanassie Sandstone Fynbos

VT 70 False Macchia (77%), VT 25 Succulent Mountain Scrub (Spekboomveld) (22%) (Acocks 1953). Dry Mountain Fynbos (65%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (74%), VT 63 South & South-east Coast Renosterveld (22%) (Low & Rebelo 1996). BHU 70 Kamanassie Mountain Fynbos Complex (77%), BHU 44 Uniondale Inland Renosterveld (19%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: On northern slopes of the Kammanassie Mountains with an extension on to Keurfonteinrant between Dysselsdorp and Uniondale. Altitude 500–1 800 m. (The highest peak of the Kammanassie—Mannetjiesberg at 1 955 m—probably supports altimontane fynbos; see FFs 31 Swartberg Altimontane Sandstone Fynbos.)

Vegetation & Landscape Features Steep to gentle, rugged northern slopes with extensive upland plateau. The vegetation comprises restiolands, often with a proteoid overstorey. Proteoid, restioid and grassy fynbos present, with prominent asteraceous fynbos. Lower slopes grade into Succulent Karoo at lowermost reaches.

Geology & Soils Acidic lithosol soils derived from Ordovician sandstones of the Table Mountain Group (Cape Supergroup). Land types mainly Ic, Ib and Fc.

Climate MAP 290–940 mm (mean: 485 mm), peaking slightly in March, but otherwise even with a low from December to February. Mean daily maximum and minimum temperatures 29.1°C and 2.0°C for January and July, respectively. Frost incidence 10–40 days per year. See also climate diagram for FFs 25 North Kammanassie Sandstone Fynbos (Figure 4.21).

Important Taxa ([T]Cape thickets) Small Tree: *Protea nitida* (d). Succulent Tree: *Aloe ferox*. Tall Shrubs: *Aspalathus hystrix* (d), *Chrysanthemoides monilifera* (d), *Dodonaea viscosa* var. *angustifolia*, *Euclea undulata*[T], *Montinia caryophyllacea*, *Phylica paniculata*, *Polygala fruticosa*, *Protea eximia*, *P. neriifolia*, *P. punctata*, *P. repens*, *Rhus pallens*[T], *R. tomentosa*[T]. Low Shrubs: *Elytropappus adpressus* (d), *Eriocephalus africanus* var. *africanus* (d), *Metalasia pungens* (d), *Agathosma affinis*, *Anthospermum aethiopicum*, *Clutia polifolia*, *Elytropappus gnaphaloides*, *Felicia filifolia* subsp. *filifolia*, *Helichrysum teretifolium*, *Leucadendron rubrum*, *L. salignum*, *Leucospermum wittebergense*, *Lobostemon fruticosus*, *Metalasia pallida*, *Muraltia dispersa*, *M. ericaefolia*, *Oedera squarrosa*, *Pelargonium myrrhifolium*, *Pentzia elegans*, *Printzia polifolia*, *Protea lorifolia*, *Pteronia stricta*, *Senecio juniperinus*. Succulent Shrub: *Crassula biplanata*. Herb: *Corymbium africanum*. Geophytic Herbs: *Androcymbium capense*, *Asplenium cordatum*, *Eriospermum capense*, *Oxalis punctata*. Graminoids: *Pentaschistis tortuosa* (d), *Themeda triandra* (d), *Cannomois scirpoides*, *Ficinia ramosissima*, *Ischyrolepis triflora*.

Endemic Taxa Low Shrubs: *Erica annalis*, *E. kammanassieae*. Geophytic Herbs: *Bobartia paniculata*, *Romulea vlokii*.

Conservation Least threatened. Target 27%. Statutorily conserved (66%) in the Kammanassie Nature Reserve, with an additional 13% in the Kammanassie Mountain catchment area. Only very little transformed and the only notable woody alien is *Hakea sericea*. Erosion low and moderate.

Reference Cleaver et al. (2005).

FFs 26 South Kammanassie Sandstone Fynbos

VT 70 False Macchia (85%) (Acocks 1953). Mesic Mountain Fynbos (64%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (88%) (Low & Rebelo 1996). BHU 70 Kamanassie Mountain Fynbos Complex (86%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: On the southern slopes of the Kammanassie Mountains between Dysselsdorp and Uniondale. Altitude 600–1 800 m. (Mannetjiesberg at 1 955 m—the highest peak of the Kammanassie—supports altimontane fynbos; see FFs 31 Swartberg Altimontane Sandstone Fynbos.)

Vegetation & Landscape Features Steep to precipitous upper southern slopes, with gentler foot slopes, well dissected and rugged. Vegetation comprises a tall proteoid shrubland and heathland. Predominantly restioid, ericaceous and proteoid fynbos, with some asteraceous fynbos on lower slopes. The old African surface conglomerates support *Dodonaea*-dominated fynbos.

Geology & Soils Acidic lithosol soils derived from Ordovician sandstones of the Table Mountain Group (Cape Supergroup), Glenrosa and Mispah forms prominent. Land types mainly Ib, Ic and Fb.

Climate MAP 310–1 150 mm (mean: 690 mm), even with no peak, but with a low from December to February. Mean daily maximum and minimum temperatures 29.0°C and 2.3°C for January and July, respectively. Frost incidence 10–30 days per year. See also climate diagram for FFs 26 South Kammanassie Sandstone Fynbos (Figure 4.21).

Important Taxa Small Tree: *Protea nitida* (d). Tall Shrubs: *Leucadendron rubrum*, *Protea eximia*, *P. neriifolia*, *P. punctata*, *P. repens*. Low Shrubs: *Acmadenia maculata*, *Amphithalea parvifolia*, *Aspalathus collina* subsp. *luculenta*, *A. patens*, *Cyclopia intermedia*, *Dolichothrix ericoides*, *Erica simulans*, *E. uberiflora*,

L. Mucina

Figure 4.46 FFs 26 South Kammanassie Sandstone Fynbos: Young proteoid fynbos with *Protea neriifolia* in the Potjiesrivier Pass near Uniondale (Western Cape).

Euryops bolusii, *Felicia esterhuyseniae*, *Helichrysum teretifolium*, *Lachnaea glomerata*, *Leucadendron salignum*, *L. singulare*, *L. spissifolium* subsp. *fragrans*, *Leucospermum royenifolium*, *Metalasia strictifolia*, *Protea intonsa*, *P. tenax*. Geophytic Herb: *Moraea cookii*. Graminoid: *Thamnochortus stokoei*.

Endemic Taxa Low Shrubs: *Erica inordinata*, *E. montis-hominis*, *Phylica floccosa*. Succulent Shrub: *Ruschia esterhuyseniae*. Geophytic Herb: *Geissorhiza elsiae*. Graminoid: *Elegia altigena*.

Conservation Least threatened. Target 27%. Statutorily conserved (13%) in the Kammanassie Nature Reserve, with an additional 57% enjoying protection in a private conservation area also carrying the name Kammanassie. Only 4% has been transformed. Alien *Hakea sericea* and *Pinus pinaster* scattered over large areas. Erosion low. Extraction of water is apparently drying up seepages and springs on the western edge of this unit.

Remarks The southern slopes of the Kammanassie are poorly explored. This unit is clearly related to the Swartberg Sandstone Fynbos units and could possibly have been included within it. However, many of the shared taxa are high-altitude species, with low-altitude species having more in common with FFs 27 Kouga Sandstone Fynbos.

Reference Cleaver et al. (2005).

FFs 27 Kouga Sandstone Fynbos

VT 70 False Macchia (87%) (Acocks 1953). Mesic Mountain Fynbos (76%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (81%) (Low & Rebelo 1996). BHU 72 Kouga Mountain Fynbos Complex (44%), BHU 73 Baviaanskloof Mountain Fynbos Complex (16%), BHU 74 Cockscomb Mountain Fynbos Complex (16%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western and Eastern Cape Provinces: Main area from the Dieprivier and the ridge of Bak se Baken in the west, through Uniondale, eastwards along the main chain of the Kouga Mountains (and continuous with some small ridges such as Ouposberg and Dwarsberg to the northwest), interrupted by the thicket of the Kouga River, and terminating in the vicinity of Blouberg. A narrower band occurs along the upper and generally south-facing parts of the Baviaanskloofberge on the northern side of Baviaanskloof from the Winterhoekberge in the west and continuing up to the gorge of the Groot River. The unit is found at high altitudes (with a southerly aspect) on the main ridge of the Groot Winterhoekberge to the high mountain parts above Uitenhage (e.g. Vermaakskop) and also occurs on some subsidiary high ridges to the south. Also found along the higher and south-facing parts of the Elandsberg as well as on the Van Stadensberg to near Fitches Corner. A narrow band occurs on the southern slopes of the Suuranysberge on the northern side of the lower Langkloof Valley, Kareedouw. Altitude 400–1 758 m (Cockscomb Peak in the Groot Winterhoekberge).

Vegetation & Landscape Features Mainly long, rounded mountain chains with moderately steep to gentle slopes. The high-altitude slopes support communities dominated by low fynbos. As is typical for this fynbos, the intermediate slopes support three strata, with Proteaceae shrubs forming the dominant tall shrub stratum. Wet, mesic and dry variations occur.

Geology & Soils Acidic lithosol soils derived from sandstones of the Table Mountain Group as well as quartzitic sandstones of the Witteberg Group (Nardouw Subgroup). Land types mainly Ib, Ic and Fa.

Climate MAP 270–910 mm (mean: 600 mm), with a slight bimodal peak in March and October. Mean daily maximum and minimum temperatures 27.3°C and 2.9°C for February and July, respectively. Frost incidence 10–40 days per year. See also climate diagram for FFs 27 Kouga Sandstone Fynbos (Figure 4.21).

Important Taxa ([T]Cape thickets) Small Trees: *Protea nitida*, *Widdringtonia schwarzii*. Tall Shrubs: *Euryops virgineus*, *Leucadendron eucalyptifolium*, *L. loeriense*, *L. uliginosum* subsp. *glabratum*, *Metalasia trivialis*, *Passerina falcifolia*, *Protea lorifolia*, *P. mundii*, *P. neriifolia*, *P. punctata*, *P. repens*, *Rhus lucida*[T], *Smelophyllum capense*[T]. Low Shrubs: *Leucadendron comosum* subsp. *comosum* (d), *Agathosma capensis*, *A. kougaense*, *Anisodontea scabrosa*, *Anthospermum galioides* subsp. *galioides*, *Aspalathus collina* subsp. *collina*, *Cliffortia arcuata*, *Diosma prama*, *D. rourkei*, *Erica angulosa*, *E. copiosa*, *E. cordata*, *E. demissa*, *E. hispidula*, *E. nabea*, *E. newdigateae*, *E. pectinifolia*, *E. simulans*, *E. strigilifolia*, *E. thamnoides*, *E. umbelliflora*, *Euryops munitus*, *E. rehmannii*, *E. spathaceus*, *Leucadendron pubibracteolatum*, *L. salignum*, *Leucospermum cuneiforme*, *Metalasia strictifolia*, *Otholobium pictum*, *Passerina obtusifolia*, *P. pendula*, *Penaea cneorum* subsp. *ovata*, *Phylica axillaris*, *P. lachneaeoides*, *Protea foliosa*, *P. vogtsiae*, *Pteronia teretifolia*, *Stoebe spiralis*. Herb: *Senecio pauciflosculosus*. Succulent Herbs: *Quaqua pillansii*, *Stapelia obducta*, *S. paniculata*. Graminoids: *Anthochortus crinalis*, *Brachiaria serrata*, *Elegia vaginulata*, *Ficinia gracilis*, *Hypodiscus aristatus*, *H. striatus*, *Ischyrolepis gaudichaudiana*, *Mastersiella purpurea*, *Merxmuellera arundinacea*, *M. stricta*, *Pentameris distichophylla*, *P. macrocalycina*, *Restio triticeus*, *Rhodocoma fruticosa*, *Tetraria cuspidata*.

Endemic Taxa Tall Shrub: *Cyclopia longifolia*. Low Shrubs: *Agathosma martiana*, *A. unicarpellata*, *Aspalathus lanceicarpa*, *Cyclopia filiformis*, *Erica abelii*, *E. affinis*, *E. bolusanthus*, *E. flocciflora*, *E. harveyana*, *E. humansdorpensis*, *E. kougabergensis*, *E. sagittata*, *E. saptouensis*, *Euryops integrifolius*, *E. ursinoides*,

S.M. Proches

Figure 4.47 FFs 27 Kouga Sandstone Fynbos: Dry grassy fynbos with abundant *Ehrharta*-dominated undergrowth and grazing red hartebeest (*Alcelaphus buselaphus*) in the Baviaanskloof Conservation Area (Eastern Cape).

Leucadendron orientale, *L. sorocephalodes*, *Paranomus esterhuyseniae*, *P. reflexus*, *Senecio oederiifolius*.

Conservation Least threatened. Target 23%. About 40% statutorily conserved in wilderness areas such as the Kouga, Guerna, Groendal, Baviaanskloof and Berg Plaatz as well as in other nature reserves such as Stinkhoutsberg and Lady Slipper and in Longmore State Forest. An additional 4% protected in private conservation areas such as Hankey Forest Reserve, Kouga, Sepree River, Sustersdal and Van Stadensberg. About 8% transformed (pine plantations, cultivation). *Pinus pinaster*, *Hakea sericea* and *Acacia saligna* are the main alien woody plants of concern. Much transformed by conversion to grassy pasture by too frequent burning. Erosion mostly low and very low.

Remark This unit also comprises patches of renosterveld vegetation on the heavier soils with higher clay content, which we did not map due to lack of information.

References Cowling & Campbell (1983a, b, 1984), Cowling (1984), Campbell (1985), Euston-Brown (1995), Boshoff et al. (2000), Vlok & Euston-Brown (2002).

FFs 28 Kouga Grassy Sandstone Fynbos

VT 70 False Macchia (82%) (Acocks 1953). Mesic Grassy Fynbos (81%) (Moll & Bossi 1983). LR 65 Grassy Fynbos (83%) (Low & Rebelo 1996). BHU 21 Humansdorp Grassy Fynbos (26%), BHU 74 Cockscomb Mountain Fynbos Complex (24%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western and Eastern Cape Provinces: Between Uniondale and Uitenhage, generally surrounding FFs 27 Kouga Sandstone Fynbos at lower altitudes and often on northerly aspects. Along the lower flanks of the Kouga Mountains in the Langkloof north of Joubertina and the northern and lower slopes of the Suuranysberge to the low mountains and flats north of Humansdorp. Along the lower slopes of the Kouga and Baviaanspoort Mountains in Baviaanspoort as well as the northern slopes of the Baviaanspoort Mountains and the northern and lower slopes of the Groot Winterhoekberge, Elandsberge and Van Stadensberg including the valleys of the upper reaches of the Elands and Kwa-Zunga Rivers. Also on various ridges embedded in FRs 16 Uniondale Shale Renosterveld south to east of Willowmore including Antoniesberg and Witberg. Altitude 220–1 220 m, mainly 300–900 m (concentrated around 480–560 m).

Vegetation & Landscape Features Low shrubland with sparse, emergent tall shrubs and dominated by grasses in the undergrowth, or grassland with scattered ericoid shrubs. The lower dry slopes, where leaching is less severe and nutrient levels are higher, support a higher grassy cover.

Geology & Soils Acidic lithosol soils derived from sandstones of the Table Mountain Group as well as quartzitic sandstones of the Witteberg Group (Nardouw Subgroup). Glenrosa and Mispah forms prominent. Land types mainly Ib and Fa.

Climate MAP 270–800 mm (mean: 540 mm), evenly throughout the year with a slight peak in March and October–November. Mean daily maximum and minimum temperatures 27.0°C and 4.2°C for February and July, respectively. Frost incidence 2–10 days per year. See also climate diagram for FFs 28 Kouga Grassy Sandstone Fynbos (Figure 4.21).

Important Taxa Small Tree: *Protea nitida*. Succulent Tree: *Aloe ferox*. Tall Shrubs: *Aspalathus kougaensis*, *A. nivea*, *Dodonaea viscosa* var. *angustifolia*. Low Shrubs: *Agathosma mucronulata*, *A. pilifera*, *A. puberula*, *A. spinosa*, *Aspalathus fourcadei*, *Cliffortia drepanoides*, *Clutia alaternoides*, *C. polifolia*, *Diosma prama*, *D. rourkei*, *Disparago ericoides*, *Erica demissa*, *E. pectinifolia*, *E. sparsa*, *E. thamnoides*, *Euryops euryopoides*, *Helichrysum teretifolium*, *Leucadendron salignum*, *Leucospermum cuneiforme*, *Otholobium carneum*, *Passerina obtusifolia*, *P. pen-*

S.M. Proches

Figure 4.48 FFs 28 Kouga Grassy Sandstone Fynbos: Grassy fynbos patch in sandstone fynbos with *Themeda triandra* and *Aloe ferox* above Geelhoutbos in the Baviaanskloof Conservation Area (Eastern Cape).

dula, *Phylica axillaris*, *P. lachneaeoides*, *Polygala myrtifolia*, *Protea foliosa*, *Pteronia incana*, *Stoebe plumosa*, *Tephrosia capensis*. Herbs: *Alepidea capensis*, *Centella virgata*, *Gazania krebsiana* subsp. *krebsiana*, *Helichrysum felinum*, *Knowltonia capensis*. Geophytic Herbs: *Bobartia orientalis* subsp. *orientalis*, *Geissorhiza roseoalba*, *Watsonia meriana*. Graminoids: *Anthochortus crinalis*, *Brachiaria serrata*, *Cannomois scirpoides*, *C. virgata*, *Cymbopogon marginatus*, *Digitaria eriantha*, *Diheteropogon filifolius*, *Eragrostis curvula*, *Heteropogon contortus*, *Hypodiscus albo-aristatus*, *H. striatus*, *H. synchroolepis*, *Ischyrolepis capensis*, *I. gaudichaudiana*, *Mastersiella purpurea*, *Melinis repens* subsp. *repens*, *Merxmuellera papposa*, *M. stricta*, *Pentameris distichophylla*, *Pentaschistis eriostoma*, *P. pallida*, *Restio triticeus*, *Rhodocoma fruticosa*, *Tetraria capillacea*, *T. cuspidata*, *T. fourcadei*, *T. involucrata*, *Thamnochortus fruticosus*, *Themeda triandra*, *Trachypogon spicatus*, *Tristachya leucothrix*.

Endemic Taxa Tall Shrub: *Freylinia crispa*. Low Shrubs: *Argyrolobium parviflorum*, *A. trifoliatum*, *Cullumia cirsioides*, *Eriocephalus tenuipes*, *Euchaetis vallis-simiae*, *Sutera cinerea*. Succulent Shrub: *Lampranthus lavisii*. Herbs: *Annesorhiza thunbergii*, *Aster laevigatus*, *Centella didymocarpa*, *Peucedanum dregeanum*. Geophytic Herbs: *Cyrtanthus flammosus*, *C. labiatus*, *C. montanus*, *Gladiolus uitenhagensis*. Succulent Herb: *Gasteria glauca*. Graminoid: *Restio vallis-simius*.

Conservation Least threatened. Target 23%. About 20% conserved in wilderness and conservation areas including the Baviaanskloof, Berg Plaatz, Groendal, Guerna, Kouga, Welbedacht State Forest, and in Mierhoopplaat and Stinkhoutsberg Nature Reserves. About 2% in addition enjoy protection in private reserves such as Jumanji Game Farm, Rooi Banke Forest Reserve, Paardekop Game Farm, Thaba Manzi Game Farm, and in Beakosneck, Kouga and Sepree River Private Nature Reserves. Some 9% transformed (cultivation) but in addition much transformed to grassy pasture by too frequent burning. Notable aliens include *Pinus pinaster*, *Acacia cyclops* and *A. mearnsii*. Erosion very low and low, but also high in some areas.

References Cowling & Campbell (1983a, b, 1984), Cowling (1984), Campbell (1985), Euston-Brown (1995), Boshoff et al. (2000), Vlok & Euston-Brown (2002).

FFs 29 Algoa Sandstone Fynbos

VT 70 False Macchia (74%), VT 2 Alexandria Forest (26%) (Acocks 1953). South Coast Renosterveld (28%) (Moll & Bossi 1983). LR 63 South and South-west Coast Renosterveld (75%), LR 65 Grassy Fynbos (23%) (Low & Rebelo 1996). BHU 22 Algoa Grassy Fynbos (62%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Eastern Cape Province: Coastal flats at Port Elizabeth from Van Stadens River in the west to Southdene-Summerstrand in the east, located mostly some kilometres from the coast and close to the coast at only Maitland River Mouth and urbanised Summerstrand. Altitude 20–300 m.

Vegetation & Landscape Features Flat to slightly undulating plain supporting grassy shrubland (mainly graminoid fynbos). Grasses become dominant especially in wet habitats. In the south this fynbos unit borders on AT 9 Albany Coastal Belt and AZs 1 Algoa Dune Strandveld and forms transitional mosaics with both. It also borders on patches of FOz 6 Southern Coastal Forest in this area.

Geology & Soils Acidic lithosol soils derived from Ordovician sandstones of the Table Mountain Group (Cape Supergroup). Land types mainly Db and Ha.

Climate MAP 560–890 mm (mean: 680 mm), evenly throughout the year, with a slight peak in March and October. Mean daily maximum and minimum temperatures 25.2°C and 7.6°C for February and July, respectively. Frost incidence about 3 days per year. See also climate diagram for FFs 29 Algoa Sandstone Fynbos (Figure 4.21).

Important Taxa Tall Shrubs: *Protea eximia*, *P. neriifolia*, *P. repens*. Low Shrubs: *Agathosma hirta*, *A. ovata*, *Erica zeyheriana*, *Euryops ericifolius*, *Helichrysum appendiculatum*, *H. teretifolium*, *Leucadendron salignum*, *L. spissifolium* subsp. *phillipsii*, *Leucospermum cuneiforme*, *Protea cynaroides*, *P. foliosa*, *Tephrosia capensis*. Succulent Herb: *Crassula pellucida* subsp. *marginalis*. Graminoids: *Andropogon eucomus*, *Brachiaria serrata*, *Cymbopogon pospischilii*, *Cynodon dactylon*, *Digitaria eriantha*, *Ehrharta calycina*, *Eustachys paspaloides*, *Ischyrolepis capensis*, *Pentaschistis heptamera*, *P. pallida*, *Thamnochortus cinereus*, *Themeda triandra*, *Tristachya leucothrix*.

Endemic Taxa ([W]Wetlands) Low Shrubs: *Agathosma gonaquensis*, *Cyclopia pubescens*[W], *Erica etheliae*. Geophytic Herb: *Holothrix longicornu*.

Conservation Endangered. Target 23%. About 2% conserved in the Van Stadens Wild Flower Reserve, The Island Nature Reserve as well as in several private nature reserves. More than 50% transformed (cultivation, urban sprawl of the Nelson Mandela Metropolitan Area). Several Australian *Acacia* species occur as invasive aliens, but only to a limited extent. Erosion moderate and very low.

Reference Vlok & Euston-Brown (2002).

FFs 30 Western Altimontane Sandstone Fynbos

VT 69 Macchia (100%) (Acocks 1953). Mesic Mountain Fynbos (95%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (100%) (Low & Rebelo 1996). BHU 52 Matroosberg Mountain Fynbos Complex (70%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Summits and top ridges from around 1 800 m upwards including patches on Jurie se Berg (Sneeukoppe; 1 930 m), Shadow Peak (1 898 m) and Sneeuberg (2 026 m) in the Cederberg, Sneeukop (2 071 m) in Skurweberge, Groot Winterhoek Peak (2 078 m), Eureka Peak (1 987 m), Medina Peak (1 905 m) and Sneeugat Peak (1 884 m), Groot Winterhoek, as well as a series of larger patches along the Hex River Mountains on Mosterthoek Twins (2 030 m), Waaihoek Peak (1 948 m), Mount Superior (1 913 m), Fonteintjiesberg (1 989 m), Sentinel Peak (1 939 m), Buffelshoek Peak (2 059 m), Milner Peak (1 995 m), Groothoek Peak (2 099 m), Rooiberg (2 209 m), Sonkliprug (2 100 m) and Matroosberg (2 249 m). This unit includes Keeromsberg (2 071 m) situated in the extreme west of the Langeberg as well as Du Toits Peak (1 994 m) in the Du Toitsberge.

Vegetation & Landscape Features High-altitude summit peaks, generally fragmented and localised, but relatively extensive in the Hex River Mountains. Vegetation in these high-altitude positions is low, open to medium dense restioid fynbos, with ericaceous and asteraceous fynbos occurring locally. Proteoid fynbos generally absent.

Geology & Soils Skeletal and rocky acidic lithosol soils derived from Ordovician sandstones of the Table Mountain Group (Cape Supergroup). Land types mainly Ic and Ib.

Climate MAP generally 450–3 140 mm (mean: 1 385 mm), peaking May to August. Mean daily maximum and minimum

L. Mucina

Figure 4.49 FFs 30 Western Altimontane Sandstone Fynbos: View of the Matroosberg massif (Hex River Mountains, Western Cape) with Conical Peak on the left and precipices of the head of the Groothoek Valley on the right. The mountain tops support altimontane sandstone fynbos, while the smooth slopes of Conical Peak and the Matroosberg show the position of the shale band of Cedarberg Formation.

temperatures 22.9°C and 0.1°C for February and July, respectively. Microclimatical measurements at altitudes of about 1 900 m on Waaihoek Peak (Boelhouwers 1998) revealed that diurnal frost cycles occur from May to September. The annual precipitation totals 2 488 mm at Waaihoek Peak, 77% of which falls during the freeze/thaw season. Presence of snow estimated to occur on 31 days per year. Unlike on shale (see a note under FFb 2), despite 74 frost days a year at Waaihoek Peak, no evidence in favour of soil needle-ice formation observed. See also climate diagram for FFs 30 Western Altimontane Sandstone Fynbos (Figure 4.21).

Important Taxa Tall Shrub: *Protea punctata*. Low Shrubs: *Acmadenia teretifolia*, *Aspalathus aristata*, *A. bodkinii*, *A. brevicarpa*, *A. pedicellata*, *Athanasia elsiae*, *Brunia macrocephala*, *Cyclopia alpina*, *C. montana* var. *glabra*, *Disparago pilosa*, *Dolichothrix ericoides*, *Erica oresigena*, *Euryops glutinosus*, *E. othonnoides*, *Helichrysum zwartbergense*, *Lachnaea alpina*, *L. laniflora*, *L. macrantha*, *L. pendula*, *Metalasia phillipsii* subsp. *incurva*, *Oreoleysera montana*, *Passerina truncata* subsp. *monticola*, *Polyarrhena imbricata*, *Prismatocarpus alpinus*, *P. decurrens*, *Protea effusa*, *P. scabriuscula*, *P. scolopendriifolia*, *Selago oresigena*, *Spatalla confusa*, *S. incurva*, *Syncarpha dykei*, *Tittmannia laxa*. Semiparasitic Shrub: *Thesium oresigenum*. Herbs: *Trieenea glutinosa*, *Ursinia sericea*. Geophytic Herbs: *Geissorhiza alticola*, *G. hesperanthoides*, *G. rupicola*, *G. scopulosa*, *G. unifolia*. Graminoids: *Askidiosperma insigne*, *Cannomois nitida*, *Ehrharta calycina*, *E. rupestris* subsp. *rupestris*, *Elegia esterhuyseniae*, *E. filacea*, *Ficinia gydomontana*, *Ischyrolepis laniger*, *I. nana*, *I. ocreata*, *I. pygmaea*, *I. virgea*, *Pentaschistis alticola*, *P. ampla*, *P. densifolia*, *P. montana*, *P. pallida*, *P. pyrophila*, *P. rigidissima*, *P. rosea* subsp. *purpurascens*, *Restio nodosus*, *R. strobolifer*, *Thamnochortus acuminatus*, *Willdenowia stokoei*.

Endemic Taxa Low Shrubs: *Agathosma foleyana*, *A. tulbaghensis*, *Amphithalea esterhuyseniae*, *A. purpurea*, *Cliffortia esterhuyseniae*, *Cyclopia glabra*, *Erica brevicaulis*, *E. cameronii*, *Phylica intrusa*. Succulent Shrub: *Esterhuysenia alpina*. Herb: *Helichrysum solitarium*.

Conservation Least threatened. Target 29%. Statutorily conserved (35%) in the Cederberg and Groot Winterhoek Wilderness Areas as well as Bokkeriviere Nature Reserve, with an additional 65% in areas such as the Matroosberg and Koue Bokkeveld Mountains catchment areas. No signs of transformation. Erosion very low.

Remark 1 This is a poorly researched unit confined to the highest mountain peaks. Although there are a few patches of this unit embedded within FFs 4 Cederberg Sandstone Fynbos and FFs 5 Winterhoek Sandstone Fynbos, most of this type lies within FFs 7 North Hex Sandstone Fynbos and FFs 8 South Hex Sandstone Fynbos. We used the 1 800 m contour to map these communities—an exploration of the variation in altitude of this type is required. In some instances it appears to occur at lower and in other cases it is still transitional at higher altitudes. Mapped areas should therefore be treated as approximate. A minimum mapping patch area of about 40 ha was applied, meaning that peaks such as Goudini Sneeukop (1 863 m) and the Cederberg's Tafelberg (1 969 m) were not included in this unit. This area requirement resulted in all mapped patches reaching an altitude of more than 1 900 m. Other possible candidates (currently unmapped) for this unit include Bokkeveld Tafelberg (1 910 m) and Baviaansberg (1 946 m) in the Kouebokkeveld and the Klein-Winterhoek Peak (1 955 m) in the Winterhoek. The question remains whether vegetation of some somewhat lower mountain peaks such as the Stettynsberge (Stettynspiek: 1 821 m) and Heksberg (1 801 m) in the northern Kouebokkeveld should be classified within this vegetation unit as well.

Remark 2 Some shale bands (Cedarberg Formation, Cape Supergroup) are found at high altitudes, but their vegetation has been mapped elsewhere (FFb 1 and FFb 2).

References Marloth (1902), Linder et al. (1993), McDonald et al. (1993), Taylor (1996).

FFs 31 Swartberg Altimontane Sandstone Fynbos

VT 70 False Macchia (100%) (Acocks 1953). Mesic Mountain Fynbos (88%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (96%) (Low & Rebelo 1996). BHU 68 Groot Swartberg Mountain Fynbos Complex (49%), BHU 66 Klein Swartberg Mountain Fynbos Complex (47%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Altitudes above 1 800 m on sandstone, from a high plateau (1 933 m) west of Towerkop, Towerkop (2 189 m), Toringberg (2 127 m) and from here stretching eastwards continuously along a long ridge culminating in the highest point in the Fynbos Biome, namely Seweweekspoort Peak (2 325 m) also occurring on the peak (1 999 m) east of the Poort, all in the Klein Swartberg Mountains. Further patches occur along the Groot Swartberg Mountains from the ridge of the Kangoberg (2 034 m) to Waboomberg (1 942 m), via various other high points including Tierberg (1 948 m) as far as Blesberg (2 084 m) in the east. The summit(s) of Mannetjiesberg (1 955 m) in the Kammanassie Mountains probably also carries this vegetation type (not mapped).

Vegetation & Landscape Features High-altitude summit peaks. The patches of this vegetation type are generally linear, trending in an east-west direction. The vegetation is low, open to medium dense restioid fynbos, also with some more localised ericaceous and asteraceous fynbos. As in FFs 30 Western Altimontane Sandstone Fynbos, proteoid fynbos is generally absent.

Geology & Soils Skeletal and rocky acidic lithosol soils derived from Ordovician sandstones of the Table Mountain Group (Cape Supergroup). Narrow shale bands run across some ridges in both the Klein and Groot Swartberg. Land types mainly Ic and Ib.

C. Boucher

Figure 4.50 FFs 31 Swartberg Altimontane Sandstone Fynbos: Dramatic sandstone ridges, peaks and rocky slopes with screes at the highest altitudes of the Klein Swartberg Mountains (Western Cape).

Climate MAP 310–900 mm (mean: 585 mm), peaking slightly in March, but relatively even with a low from December to February. Mean daily maximum and minimum temperatures 23.6°C and –1.1°C for January and July, respectively. Frost incidence 10–30 days per year. See also climate diagram for FFs 31 Swartberg Altimontane Sandstone Fynbos (Figure 4.21).

Important Taxa Low Shrubs: *Acmadenia teretifolia* (d), *Anthospermum spathulatum* subsp. *spathulatum* (d), *Erica esterhuyseniae* (d), *E. strigilifolia* (d), *Spatalla confusa* (d), *Aspalathus pedicellata*, *A. rubens*, *Cyclopia alopecuroides*, *C. burtonii*, *Helichrysum zwartbergense*, *Heliophila rimicola*, *Lachnaea buxifolia*, *L. elsieae*, *Leucadendron dregei*, *Otholobium swartbergense*, *Protea montana*, *P. rupicola*, *P. scolopendriifolia*, *P. venusta*, *Raspalia variabilis*, *Selago pulchra*, *Syncarpha montana*, *Tittmannia laxa*. Herb: *Dianthus laingsburgensis*. Geophytic Herb: *Watsonia marlothii* (d). Graminoids: *Cannomois nitida* (d), *Ehrharta rupestris* subsp. *tricostata* (d), *Elegia filacea* (d), *Ischyrolepis laniger* (d), *I. schoenoides* (d), *Pentameris macrocalycina* (d), *Rhodocoma alpina* (d), *Willdenowia stokoei* (d), *Ischyrolepis wittebergensis*, *Pentaschistis montana*, *P. rigidissima*.

Endemic Taxa Low Shrubs: *Erica toringbergensis* (d), *Calotesta alba*, *Cyclopia aurescens*, *C. bolusii*, *Erica gossypioides*, *E. hebdomadalis*, *E. jugicola*, *E. lignosa*, *E. oreotragus*, *E. roseoloba*, *Protea pruinosa*, *Selago esterhuyseniae*. Graminoids: *Pentameris glacialis* (d), *P. swartbergensis* (d), *Restio papyraceus* (d), *Thamnochortus papyraceus* (d), *Staberoha stokoei*.

Conservation Least threatened. Target 29%. Almost the entire area of the unit enjoys protection in conservation areas, including Towerkop, Klein Swartberg, Groot Swartberg and Swartberg-oos. Almost none of the area has been transformed. *Hakea sericea* can pose some invasion threat. Erosion very low.

Remark 1 There is no abrupt interface between altimontane and other sandstone fynbos types. There is a gradual change between middle-altitude communities and high-altitude communities, both structurally and floristically. More important factors are water-logging, soil depth and rockiness, which determine floristic and structural composition irrespective of altitude. Endemism and dominants are characteristic of the local species pools, with an equal amount of local and regional endemism shared between distinct altimontane sandstone fynbos sites.

Remark 2 A minimum mapping patch area of about 40 ha was applied, meaning that, for example, several small peaks on the Kammanassie Mountains (especially those around the highest point of Mannetjiesberg (1 955 m) were not included in this unit. This area requirement resulted in almost all mapped patches reaching an altitude of more than 1 900 m.

References Marloth (1902), Linder et al. (1993), McDonald et al. (1993).

9.1.2 Quartzite Fynbos

Quartzite fynbos comprises almost 10% of the area of fynbos vegetation, being the third most extensive fynbos group, after sandstone and sand fynbos. Within the Fynbos Biome it is largely confined to the more arid areas. Two vegetation types within quartzite fynbos are the only fynbos types not known to have endemic species.

Unlike most of the sandstones of the Cape Supergroup, quartzites have undergone drastic changes in location over the past 120 million years since the break-up of Gondwana. All coastal remnants (with an exception at Riversdale) and Little Karoo exposures (with the exception of remnants at Montagu and Bethal Dam) have been totally removed by erosion. Exposures on the West Coast were probably well eroded during the Cretaceous. Extensive exposures still occur on the borders of the Tanqua and Great Karoo from Wuppertal to Laingsburg. These are now generally 40 km east of the Olifants fault, 15 km north of the Swartberg fault, and—exposing the Steytlerville Karoo—some 35 km north of the Baviaanskloof fault.

Quartzite fynbos is not a geological type per se—it is merely named after the Witteberg quartzites on which it occurs most frequently. It is primarily an arid unit, characterised and distinguished from sandstone fynbos by the typically linear nature of the units, and/or by much higher levels of remnant surface clays. These appear to be derived not only from overlying geology, but also from wind and water erosion. Even a rudimentary clay soil is sufficient to exclude fynbos and result in renosterveld or karoo vegetation, except in wetter areas where it has features and species more typical of shale fynbos, and is mapped as such. Quartzite fynbos may occur in very small patches within this environment, usually along scarps and ridges. In drier areas they may be confined to a narrow linear zone (sometimes only

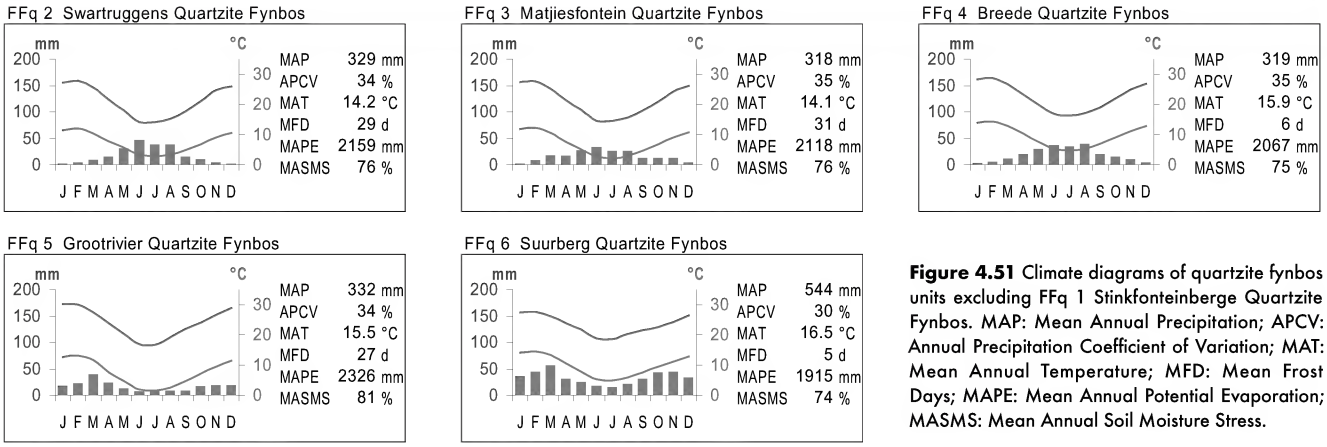


Figure 4.51 Climate diagrams of quartzite fynbos units excluding FFq 1 Stinkfonteinberge Quartzite Fynbos. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days; MAPE: Mean Annual Potential Evaporation; MASMS: Mean Annual Soil Moisture Stress.

some metres across) at the base of these scarps. It is probably a historical and topographical accident that almost all Witteberg quartzite exposures now occur in relatively arid areas. Erosion has effectively moved exposures to the inland margins of the Cape Fold Belt. It is generally true that 'quartzite fynbos' could equally be described as 'arid fynbos'. Thus the fynbos on the Witteberg quartzite in the wetter Koue Bokkeveld is grouped with FFs 5 Winterhoek Sandstone Fynbos, and not with the drier FFq 2 Swartruggens Quartzite Fynbos.

Due to its aridity, the dominant communities on quartzite fynbos are asteraceous and proteoid fynbos. Restioid fynbos occurs locally, but ericaceous fynbos is rare. Afrotemperate forest seldom occurs in quartzitic fynbos, and the fire-protected habitats tend toward Succulent Karoo or Albany Thicket vegetation instead, in the west and east of the Fynbos Biome, respectively. The two eastern units are dominated by graminoid fynbos. Waboomveld is never found to be part of quartzite fynbos.

The drier edge of these communities has not been adequately mapped. Until better data are available we have included the basal Succulent Karoo vegetation within this mapped unit. This extends further up on north facies, is usually absent on south facies, and may occur within areas expected to have fynbos where patches are too small to maintain fire (e.g. where the surrounding veld is Succulent Karoo or Albany Thicket).

FFq 1 Stinkfonteinberge Quartzite Fynbos

VT 28 Western Mountain Karoo (69%) (Acocks 1953). LR 56 Upland Succulent Karoo (100%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Central Richtersveld—a narrow belt along the top mountain ridges of the Vandersterrberg (1 366 m) east of Koeboes in the north, Cornellsberg (1 377 m) and Stinkfonteinberge (1 230 m) immediately north of Eksteenfontein in the south. Altitude about 1 100–1 377 m.

Vegetation & Landscape Features This unit forms the upper north-south-trending backbone of the Richtersveld. The landscape at the high altitudes above 1 100 m is as diverse as the geomorphology of the longitudinal mountain range. While over long distances it forms a ridge, in other places steep or rounded mountain tops are embedded, separated by saddles and valleys. In other parts, a plateau has been formed, allowing accumulation of soils above bedrock. Therefore, habitat types differ greatly and are controlled by rock structure, overlying soil depth, slope and inclination. Dense shrublands can form where soil depth and rock structure allow water storage over longer periods of the year. Flatter plateau positions on leached quartzite soils can bear open *Merxmuellera dura* grasslands, while very shallow soils and bare rock support the presence or dominance of leaf-succulent dwarf shrubs.

Geology & Soils A wide spectrum of different rocks, mostly quartzite, as well as other metamorphosed clastic sediments and minor volcanic rocks of the Stinkfontein Subgroup of the Precambrian Gariep Supergroup. Soils mainly loams or loamy sands. Land types mainly Ic.

Climate MAP probably slightly over 200 mm. Fog occurs especially on the western side. Mean daily maximum and minimum temperatures 28.8°C and 2.8°C for January and July, respectively. Frost incidence 10–20 days per year.

Important Taxa Tall Shrubs: *Euryops tenuissimus* (d), *Diospyros ramulosa*, *Helichrysum hebelepis*, *Montinia caryophyllacea*, *Rhus incisa*, *R. populifolia*. Low Shrubs: *Elytropappus rhinocerotis* (d), *Anthospermum dregei* subsp. *dregei*, *Asparagus exuvialis*, *Berkheya canescens*, *Blepharis furcata*, *Chrysocoma oblongi-*

N. Jürgens

Figure 4.52 FFq 1 Stinkfonteinberge Quartzite Fynbos: Low grassy shrubland on top of the ridge of the Stinkfonteinberge in the Richtersveld showing a matrix of *Merxmuellera dura*, *Didelta spinosa*, *Elytropappus rhinocerotis* and *Lobostemon echioides*.

folia, *Cryptolepis decidua*, *Eriocephalus africanus* var. *africanus*, *E. ericoides* subsp. *ericoides*, *Galenia africana*, *Lobostemon echioides*, *Osteospermum sinuatum*, *Pelargonium praemorsum*, *Pteronia divaricata*, *P. glauca*, *Tripteris sinuata*. Succulent Shrubs: *Othonna furcata* (d), *Aloe dichotoma* var. *ramosissima*, *Antimima pilosula*, *Aridaria brevicarpa*, *Cephalophyllum goodii*, *Ceraria fruticulosa*, *Crassula macowaniana*, *Didelta spinosa*, *Euphorbia quadrata*, *Manochlamys albicans*, *Pelargonium echinatum*, *Prenia sladeniana*, *Tylecodon paniculatus*. Woody Climbers: *Asparagus retrofractus*, *Dioscorea elephantipes*. Herbs: *Amellus epaleaceus*, *A. nanus*, *Arctotis fastuosa*, *Dimorphotheca sinuata*, *Senecio sisymbriifolius*. Geophytic Herbs: *Albuca maxima*, *Cheilanthes robusta*, *Chlorophytum namaquense*. Succulent Herbs: *Adromischus marianiae*, *Crassula expansa* subsp. *pyrifolia*, *C. hemisphaerica*, *C. muscosa*, *Tetragonia reduplicata*. Graminoids: *Merxmuellera dura* (d), *Bromus pectinatus*, *Ehrharta calycina*, *E. delicatula*, *E. longiflora*, *Fingerhuthia africana*, *Ischyrolepis sieberi*.

Conservation Least threatened (due to poor accessibility and low economic attractiveness). Conservation target (28%) already achieved since more than 30% is conserved in the Richtersveld National Park, but its southern somewhat mesic part is not formally protected. Grazing is light, with very little disturbance, and erosion is very low.

Remarks Better developed on the Stinkfonteinberge than on the Vandersterrberg, following the northward gradient of increased aridity. Apparently absent from the east-branching mountains of similar altitude, for example the Rosyntjieberg (1 332 m) associated with an eastward gradient of increased aridity in this area.

References Van Jaarsveld (1981), Van Wyk & Smith (2001), Schüttler (2002), Jürgens (2004).

FFq 2 Swartruggens Quartzite Fynbos

VT 69 Macchia (76%) (Acocks 1953). Central Mountain Renosterveld (31%), Mosaic of Dry Mountain Fynbos & Karroid Shrublands (15%), Dry Mountain Fynbos (4%) (Moll & Bossi 1983). LR 57 Lowland Succulent Karoo (54%) (Low & Rebelo 1996). BHU 49 Swartruggens Mountain Fynbos Complex (42%), BHU 36 Kouebokkeveld Inland Renosterveld (29%), BHU 78 Tanqua Vygieveld (23%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

L. Mucina

Figure 4.53 FFq 2 Swartruggens Quartzite Fynbos: *Protea glabra* on a quartzite outcrop covered with succulent shrubs (*Ruschia*, *Crassula*, *Othonna*) and annual herbs (*Ursinia anthemoides* subsp. *versicolor*) in the Swartruggens Mountains near Op-die-Berg (Western Cape).

Distribution Western and Northern Cape Provinces: West of the Cederberg from the Tra-Traberge north of Wuppertal, interrupted by the Tra-Tra River Valley, continuing on the high plateau including the Vaalheuningberge, Matjiesrivier, Klipbokberg, Rietriviersberg, eastern Blinkberg, continuing on the Swartruggens Plateau, Vleieberg, Watervalsberg, Baviaansberg and Kwarrieberg at Karoopoort in the south. Altitude 800–1 800 m. The area above 1 800 m on Baviaansberg (summit 1 946 m) probably qualifies for FFs 30 Western Altimontane Sandstone Fynbos.

Vegetation & Landscape Features Mountains alternating with broad ridges and plains, supporting medium dense, moderately tall, restioid and ericoid shrubland with open, emergent, tall proteoid shrubs. This is a diverse fynbos, with all structural types of fynbos (except graminoid fynbos) represented. In drier, lower areas it is replaced by karoo shrublands on sandstone. The boundary between the fynbos and karoo occurs where the restioids thin out to the point where succulent plants become dominant.

Geology & Soils Sandy and skeletal soils (usually of Glenrosa or Mispah forms) derived from Witteberg Group quartzite. Land types mainly Ib and Fa.

Climate Subarid, winter-rainfall regime with MAP 200–620 mm (mean: 330 mm), peaking from May to August. Mean daily maximum and minimum temperatures 27.9°C and 2.7°C for February and July, respectively. Frost incidence 10–20 days per year. See also climate diagram for FFq 2 Swartruggens Quartzite Fynbos (Figure 4.51).

Important Taxa ([T]Cape thickets) Tall Shrubs: *Phylica buxifolia* (d), *Protea glabra* (d), *Dodonaea viscosa* var. *angustifolia*, *Euryops speciosissimus*, *Leucadendron pubescens*, *Metalasia densa*, *Passerina corymbosa*, *Protea laurifolia*. Low Shrubs: *Elytropappus rhinocerotis* (d), *Erica maximiliani* (d), *Agathosma squamosa*, *Aspalathus altissima*, *A. bodkinii*, *Athanasia flexuosa*, *Diosma acmaeophylla*, *Dolichothrix ericoides*, *Elytropappus glandulosus*, *Erica rigidula*, *Eriocephalus africanus* var. *africanus*, *E. africanus* var. *paniculatus*, *E. ericoides* subsp. *ericoides*, *Euryops brevilobus*, *E. othonnoides*, *E. rehmannii*, *E. tagetoides*, *Felicia scabrida*, *Leucadendron brunioides* var. *brunioides*, *L. glaberrimum* subsp. *glaberrimum*, *L. loranthifolium*, *L. nitidum*, *Leucospermum calligerum*, *Maytenus oleoides*[T], *Metalasia agathosmoides*, *Muraltia lignosa*, *Passerina obtusifolia*, *P. truncata* subsp. *truncata*, *Phylica odorata*, *P. rigidifolia*, *Protea laevis*, *P. pendula*, *P. witzenbergiana*, *Pteronia incana*, *Stoebe fusca*, *Ursinia pilifera*. Succulent Shrub: *Othonna coronopifolia*. Geophytic Herb: *Romulea sphaerocarpa*. Succulent Herb: *Stapelia arenosa*. Graminoids: *Ficinia dunensis* (d), *Ischyrolepis unispicata* (d), *Willdenowia incurvata* (d), *Cannomois scirpoides*, *C. taylorii*, *Elegia filacea*, *Ischyrolepis capensis*, *I. ocreata*, *Pentaschistis eriostoma*, *Thamnochortus schlechteri*.

Endemic Taxa Low Shrubs: *Amphiglossa susannae*, *Nenax elsieae*, *Oedera epaleacea*, *O. foveolata*, *Phylica pauciflora*, *Vexatorella amoena*. Succulent Shrubs: *Esterhuysenia mucronata*, *Ruschia littlewoodii*. Herb: *Phyllopodium viscidissimum*. Geophytic Herbs: *Moraea fuscomontana*, *Romulea lilacina*.

Conservation Least threatened. Target 29%. Only 4% statutorily conserved in the Matjiesrivier Nature Reserve, with an additional 5% protected in Groenfontein Private Nature Reserve. Only 2% has been transformed (mainly cultivation). Erosion generally low.

Remark The delimitation of this unit and the neighbouring SVk 2 Swartruggens Quartzite Karoo follows the boundary rules as suggested by Lechmere-Oertel (1998).

References Boucher (1996a), Lechmere-Oertel (1998), Lechmere-Oertel & Cowling (1999, 2001), H.C. Taylor (unpublished data).

FFq 3 Matjiesfontein Quartzite Fynbos

VT 70 False Macchia (43%), VT 69 Macchia (19%) (Acocks 1953). Central Mountain Renosterveld (65%) (Moll & Bossi 1983). LR 61 Central Mountain Renosterveld (66%) (Low & Rebelo 1996). BHU 39 Matjies Inland Renosterveld (30%), BHU 62 Witteberg Mountain Fynbos Complex (22%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: A complex of ridges and low mountains mostly in the Western Little Karoo extending from Saalberg near Karoopoort and Skulpiesklip in the west to Elandsberg near the Gamkapoort Dam in the east. This includes parts of the Bontberg, Voetpadsberg and Koegaberge in the vicinity of Touws River, the Witteberg south of Matjiesfontein including many ridges between the Witteberg and Anysberg, and the higher ridges north of, and running parallel to, the Klein Swartberg. Also between Ouberg Pass and Gatskraal (Mont Eco) west of Warmwaterberg and on hill summits around Ladismith, including Ladismith Hill. Altitude 750–1 684 m at an unnamed point north of Towerkop.

Vegetation & Landscape Features Low flat mountains and parallel ridges in a west-east orientation. Apart from the Witteberg and Elandsberg, this vegetation type consists of narrow, linear bands surrounded by FFh 2 Matjiesfontein Shale Fynbos and Succulent Karoo vegetation. It is a medium dense, medium tall shrubland, structurally classified mainly as asteraceous and proteoid fynbos, although restioid fynbos is also present. The lower northern slopes in the east, where there is a rainshadow effect due to the Swartberg Mountains, support Succulent Karoo vegetation.

P. Goldblatt

Figure 4.54 FFq 3 Matjiesfontein Quartzite Fynbos: Dry proteoid fynbos with *Leucadendron teretifolium, Protea canaliculata* and *P. lorifolia* on the summit of the Witteberg near the FM tower south of Matjiesfontein (Western Cape).

Geology & Soils Sandy and skeletal soils derived from Witteberg Group quartzites. Land types mainly Ic, Ib and Fc.

Climate MAP 150–450 mm (mean: 320 mm), peaking slightly from May to August. Mean daily maximum and minimum temperatures 27.5°C and 2.2°C for February and July, respectively. Frost incidence 10–40 days per year. See also climate diagram for FFq 3 Matjiesfontein Quartzite Fynbos (Figure 4.51).

Important Taxa Tall Shrubs: *Protea laurifolia* (d), *P. repens* (d), *Leucadendron pubescens*, *L. rubrum*, *Nylandtia spinosa*, *Phylica buxifolia*. Low Shrubs: *Agathosma squamosa*, *Amphiglossa tomentosa, Diosma hirsuta*, *Elytropappus rhinocerotis*, *Erica cerinthoides* var. *cerinthoides*, *E. plukenetii* subsp. *plukenetii*, *E. rigidula*, *Euryops erectus*, *E. oligoglossus* subsp. *oligoglossus*, *E. rehmannii*, *Leucadendron barkerae*, *L. cadens*, *L. salignum*, *L. teretifolium*, *Polygala myrtifolia*, *Protea canaliculata*, *P. lorifolia*, *P. pendula*, *P. revoluta*, *P. sulphurea*, *Stoebe plumosa*, *Vexatorella obtusata* subsp. *albomontana*. Succulent Herb: *Quaqua pillansii*. Graminoids: *Ischyrolepis capensis*, *Thamnochortus fruticosus*, *Willdenowia incurvata*.

Endemic Taxa Tall Shrub: *Leucadendron osbornei*. Low Shrubs: *Acmadenia argillophila*, *Aspalathus intricata* subsp. *anthospermoides*, *Chrysocoma acicularis*, *Erica mira*, *Globulariopsis montana*, *G. wittebergensis*, *Helichrysum archeri*, *Hermannia pillansii*, *Phylica retorta*, *Selago albomontana*. Succulent Shrubs: *Drosanthemum archeri*, *D. wittebergense*, *Ruschia altigena*. Herb: *Senecio wittebergensis*. Geophytic Herb: *Ornithogalum unifolium* var. *vestitum*. Succulent Herb: *Haworthia wittebergensis*. Graminoids: *Ischyrolepis esterhuyseniae*, *I. karooica*.

Conservation Least threatened. Target 27%. Statutorily conserved in the Anysberg Nature Reserve (5%) and a further 3% in Vaalkloof Private Nature Reserve. Only about 15% has been transformed (cultivation). Erosion low and moderate.

Remarks This little known vegetation requires detailed study. The southern outliers (largely unknown) near Bellair Dam (the lowest MAP in the basin of the Little Karoo) may comprise a separate unit, being biogeographically allied to the Warmwaterberg and Waboomsberg. Similarly, the outliers around Ladismith are currently unknown and their affiliation with this unit is speculative. The northernmost border with Succulent Karoo on quartzite is largely unknown and has not been accurately mapped, except at a few mountain passes, from which it has been extrapolated.

References Vlok (2002), C. Boucher (unpublished data).

FFq 4 Breede Quartzite Fynbos

VT 26 Karroid Broken Veld (52%) (Acocks 1953). Central Mountain Renosterveld (46%), Mesic Mountain Fynbos (23%) (Moll & Bossi 1983). LR 61 Central Mountain Renosterveld (51%), LR 58 Little Succulent Karoo (25%), LR 64 Mountain Fynbos (23%) (Low & Rebelo 1996). BHU 38 Ashton Inland Renosterveld (60%), Robertson Broken Veld (29%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Southern Breede River Valley from the Brandvlei Dam at Die Nekkies near Worcester to northeast of Bonnievale, but with by far the largest extent on the Hammansberg, Ouhangsberge,

Gemsbokkop, Gannaberg and Rooiberg. Altitude 200–876 m on the summit of Gannaberg.

Vegetation & Landscape Features A single range of parallel ridges and flat-topped hills in the west, and high hills and low mountains in the east. The vegetation is an open tall shrubland in a medium dense, medium tall shrub matrix, structurally classified as asteraceous, restioid and proteoid fynbos. Northern slopes tend to support karoo shrublands, especially at lower reaches.

Geology & Soils Sandy and skeletal soils (Glenrosa and Mispah forms prominent) derived from Witteberg Group quartzites. Land types mainly Ic and Fb.

Climate MAP 190–550 mm (mean: 320 mm), peaking slightly from May to August. Mean daily maximum and minimum temperatures 28.6°C and 4.7°C for February and July, respectively. Frost incidence 5–8 days per year. See also climate diagram for FFq 4 Breede Quartzite Fynbos (Figure 4.51).

A. van Niekerk

Figure 4.55 FFq 5 Grootrivier Quartzite Fynbos: Dry fynbos on the ridges of the Grootrivier Mountains, north of Steytlerville (Eastern Cape).

Important Taxa Small Tree: *Protea nitida* (d). Tall Shrubs: *Protea repens* (d), *P. laurifolia*. Low Shrubs: *Diosma ramosissima*, *Leucadendron salignum* (d), *L. teretifolium*, *Leucospermum calligerum*, *L. utriculosum* (Robertson form), *Protea humiflora*, *P. restionifolia*, *Serruria acrocarpa*.

Endemic Taxa Low Shrubs: *Erica boucheri*, *Lobostemon gracilis*.

Conservation Least threatened. Target 30%. Only very small portion statutorily conserved in the Vrolijkheid Nature Reserve, but 9% enjoys protection in the Quaggas Berg and Drooge Riviers Berg Private Nature Reserves. Some 6% has been transformed (cultivation). No aliens are found at significant densities, although *Hakea sericea* is prominent in places. Erosion very low and moderate.

Remarks This is a very poorly known unit related to FFs 13 North Sonderend Sandstone Fynbos, and perhaps best considered as part of it, but markedly more arid and typically linear. At present its delimitation is largely based on the occurrence of Proteaceae. The karoo shrublands on the northern slopes at lower reaches have simply been mapped as fynbos as their lower limits are unknown and their communities are different to Succulent Karoo shrublands on shales.

Reference Protea Atlas Project (unpublished data).

FFq 5 Grootrivier Quartzite Fynbos

VT 25 Succulent Mountain Scrub (Spekboomveld) (61%), VT 70 False Macchia (28%) (Acocks 1953). Dry Grassy Fynbos (25%) (Moll & Bossi 1983). LR 8 Spekboom Succulent Thicket (49%), LR 65 Grassy Fynbos (22%) (Low & Rebelo 1996). BHU 98 Willowmore Xeric Succulent Thicket (56%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western and Eastern Cape Provinces: Ridges north of the Groot Swartberg and Baviaanskloof Mountains, from Prince Albert to Wolwefontein west of Kirkwood, but mainly in the Grootrivierberge mostly north of the Groot River between Willowmore and Steytlerville as well as on the adjoining Witteberg north of the Grootrivierberge. Generally a very narrow strip (< 1 km wide) west of the Boesmanspoortberg at Willowmore. Separated from the most easterly quartzite fynbos unit (FFq 6 Suurberg Quartzite Fynbos) by the Wolwefontein-Baroe Valley. Altitude 650–1 579 m on the summit of the Witteberg.

Vegetation & Landscape Features A series of narrow parallel scarps, much broader, higher and more extensive in the west at Witberg. Typical vegetation is a medium dense, moderately tall, restioid and ericoid shrubland dotted with emergent, tall proteoid shrubs in the wetter west, and containing more grassy elements in the east. Proteoid fynbos is confined to the higher peaks, with asteraceous fynbos the dominant component in the west and grassy fynbos in the east. The northern edge is primarily determined by Spekboomveld, and the southern edge by other Albany Thicket communities. Grasses are relatively abundant, especially on northern slopes.

Geology & Soils Sandy and skeletal soils, often red-yellow, apedal and shallow, derived from Witteberg Group quartzite. Land types mainly Ib, Ag and Ic.

Climate MAP 160–560 mm (mean: 330 mm), peaking in March, with a low from June to September. Mean daily maximum and minimum temperatures 30.1°C and 1.4°C for January and July, respectively. Frost incidence 10–30 days per year. See also climate diagram for FFq 5 Grootrivier Quartzite Fynbos (Figure 4.51).

Important Taxa Tall Shrubs: *Leucadendron loeriense*, *L. nobile*, *Phylica paniculata*, *Protea lorifolia*, *P. punctata*, *P. repens*. Low Shrubs: *Agathosma ovalifolia*, *Cliffortia castanea*, *C. neglecta*, *Dolichothrix ericoides*, *Erica demissa*, *E. pectinifolia*, *E. petraea*, *Leucospermum wittebergense*, *Muraltia ericaefolia*, *Passerina obtusifolia*, *Struthiola argentea*. Succulent Shrub: *Euphorbia polygona*. Succulent Herb: *Stapelia obducta*. Graminoids: *Calopsis andreaeana*, *Ficinia nigrescens*, *Ischyrolepis gaudichaudiana*, *I. sieberi*, *Mastersiella purpurea*, *Thamnochortus rigidus*.

Endemic Taxa Low Shrub: *Theilera capensis*. Succulent Herb: *Ophionella willowmorensis*.

Conservation Least threatened. Target 23%. None conserved in statutory conservation areas and only 1% protected in Timbili Game Reserve. Only very small portion has been trans-

formed, incidence of alien flora is insignificant. Erosion low and very low.

Remarks This is a very poorly explored vegetation type. This unit could, based on edaphic criteria, be more widespread than it is at present, but the extent of suitable habitat complex is too small to support fires and too linear to allow their spread. Consequently, much of the quartzites is covered by dense Albany Thicket vegetation. Judging from the extent of the remnants, the unit must have been much more extensive in the past.

Reference Protea Atlas Project (unpublished data).

FFq 6 Suurberg Quartzite Fynbos

VT 70 False Macchia (64%) (Acocks 1953). Valley Bushveld (64%), Dry Grassy Fynbos (22%) (Moll & Bossi 1983). LR 65 Grassy Fynbos (37%), LR 6 Xeric Succulent Thicket (28%) (Low & Rebelo 1996). BHU 23 Zuurberg Grassy Fynbos (12%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Eastern Cape Province: From Baroe in the west along the Kleinwinterhoekberge, the Suurberge north of Kirkwood, multiple ridges in the vicinity of Somerset East and Alicedale, immediately south of Grahamstown some slopes and hills, e.g. Signal Hill to the Kaprivierberge east of Grahamstown. Altitude 350–1 010 m at the highest point in the Kleinwinterhoekberge.

Vegetation & Landscape Features Low rounded hills and mountains supporting low to medium high, closed, ericoid shrubland or grassland, with closed restioid and/or grass understorey. Grassy fynbos is the most typical structural type, with localised patches of dense proteoid and ericaceous fynbos. On drier, north-facing slopes grassland replaces this unit, but the south-facing slopes always carry fynbos unless converted to grassland by over-burning, or to thicket by over-protection from fire. Thicket is found on the richer soils at the base of the formation and in gullies.

Geology & Soils Sandy soils, predominantly Glenrosa and Mispah forms, derived from Witteberg Group quartzite. Land types mainly Fa, Fb and Ib.

Climate MAP 220–820 mm (mean: 545 mm), peaking bimodally from October–November and February–March. Mean daily maximum and minimum temperatures 27.7°C and 4.7°C for February and July, respectively. Frost incidence 2–10 days per year. See also climate diagram for FFq 6 Suurberg Quartzite Fynbos (Figure 4.51).

Important Taxa ([T]Cape thickets) Small Tree: *Loxostylis alata*. Succulent Tree: *Aloe ferox*. Tall Shrubs: *Cliffortia burchellii* (d), *C. linearifolia* (d), *Euryops latifolius* (d), *Cliffortia serpyllifolia*, *Diospyros scabrida*[T], *Grewia occidentalis*, *Montinia caryophyllacea*, *Protea lorifolia*, *P. repens*. Low Shrubs: *Clutia heterophylla* (d), *Erica chamissonis* (d), *E. demissa* (d), *E. pectinifolia* (d), *E. simulans* (d), *E. triceps* (d), *Helichrysum odoratissimum* (d), *Leucadendron salignum* (d), *Phylica axillaris* (d), *Tephrosia capensis* (d), *Acalypha peduncularis*, *Anthospermum aethiopicum*, *A. spathulatum* subsp. *uitenhagense*, *Aspalathus teres* subsp. *teres*, *Berzelia commutata*, *Cliffortia graminea*, *Clutia alaternoides*, *Disparago ericoides*, *Erica cerinthoides* var. *cerinthoides*, *E. copiosa*, *E. decipiens*, *E. glumiflora*, *E. nutans*, *Euryops brachypodus*, *E. euryopoides*, *Gnidia coriacea*, *G. oppositifolia*, *Gomphocarpus cancellatus*, *Helichrysum anomalum*, *H. cymosum*, *Leucadendron spissifolium* subsp. *phillipsii*, *Leucospermum cuneiforme*, *Muraltia squarrosa*, *Passerina obtusifolia*, *Pelargonium reniforme*, *Polygala microlopha*, *Protea cynaroides*, *P. foliosa*, *Pteronia teretifolia*, *Ursinia anethoides*. Succulent Shrubs: *Crassula cultrata* (d), *Euphorbia polygona*, *Lampranthus spectabilis*, *Othonna carnosa*. Semiparasitic Shrub: *Thesium strictum*. Herbs: *Alepidea capensis* (d), *Amellus strigosus* (d), *Cineraria saxifraga* (d), *Helichrysum nudifolium* (d), *H. subglomeratum* (d), *Senecio othonniflorus* (d), *Centella eriantha*, *Helichrysum felinum*, *Knowltonia cordata*, *Linum thunbergii*, *Sutera polyantha*, *Ursinia anthemoides* subsp. *anthemoides*. Geophytic Herbs: *Pteridium aquilinum* (d), *Agapanthus africanus*, *Bulbine latifolia*, *Oxalis imbricata* var. *violacea*, *O. punctata*, *Watsonia knysnana*. Succulent Herb: *Stapelia grandiflora*. Graminoids: *Alloteropsis semialata* subsp. *eckloniana* (d), *Cannomois virgata* (d), *Diheteropogon filifolius* (d), *Eragrostis curvula* (d), *Festuca costata* (d), *Merxmuellera stricta* (d), *Pentaschistis eriostoma* (d), *Poa binata* (d), *Restio sejunctus* (d), *R. triticeus* (d), *Schoenoxiphium sparteum* (d), *Tetraria capillacea* (d), *Themeda triandra* (d), *Tristachya leucothrix* (d), *Calopsis paniculata*, *Elegia asperiflora*, *Ficinia acuminata*, *Hyparrhenia hirta*, *Hypodiscus striatus*, *Ischyrolepis gaudichaudiana*, *I. triflora*, *Rhodocoma capensis*, *Tetraria cuspidata*.

Endemic Taxa Small Tree: *Oldenburgia grandis* (d). Low Shrubs: *Euryops hypnoides*, *E. polytrichoides*.

Conservation Least threatened. Target 23%. Statutorily conserved in the Greater Addo Elephant National Park (15%), with an additional 16% protected in the private Rockdale Game Ranch and Frontier Safaris Game Farm. Only 1% has been transformed (cultivation), but over-burning (occurring quite frequently) resulting in conversion of fynbos to grassland should be considered as transformation as well. Erosion moderate and very low.

Remarks Historically, there has been no obvious attempt to separate fynbos on quartzite and shale in this region. Protea Atlas data suggest that there may be a separation, but the lack of references in the literature suggests that any such differ-

L. Mucina

Figure 4.56 FFq 6 Suurberg Quartzite Fynbos: Quartzite ridge southwest of Grahamstown (Eastern Cape) with grassy fynbos with enigmatic local endemic tree daisy *Oldenburgia grandis* (Asteraceae).

ences are not obvious. Hence the proper delimitation of FFq 6 Suurberg Quartzite Fynbos and FFh 10 Suurberg Shale Fynbos remains a challenge.

References Dyer (1937), Martin & Noel (1960), Martin (1965, 1966), Kruger (1979), Cowling (1983b), Lubke (1983), Richardson et al. (1984), Lubke et al. (1986), Van Wyk et al. (1988), Euston-Brown (1995), Vlok & Euston-Brown (2002).

9.1.3 Sand Fynbos

Sand fynbos is the second largest unit accounting for 15% of the area of Fynbos. It is almost entirely coastal, occurring on Quaternary and Tertiary sands of marine and aeolian origin. Deep sand on the West and South Coasts reflects a broad soil-reaction gradient—spanning acidic, neutral to alkaline. All alkaline sands on the West Coast support strandveld, and on the South Coast they carry either thicket (strandveld) or dune fynbos, depending on the underlying topography and fire regime. With time the sands become leached and are invaded by sand fynbos, which should therefore strictly be called 'acid sand fynbos', although some communities may also occur on soils of neutral reaction (pH 6–7). The dominant structural type of sand fynbos depends on the water table. Where water tables are deep (access to rainfall is only in winter), restioid fynbos dominates, usually with marked absence of shrubs. Where the water table is more accessible, asteraceous fynbos may occur, usually dominated by species of *Passerina* and *Phylica*. This type usually has a marked spring-flower component, comprising both annuals and geophytes. At relatively shallow and non-fluctuating water tables proteoid fynbos dominates—one with a more closed canopy and relatively fewer annuals and geophytes. Depending on water depth, soil fertility and topography, different communities within these types can be distinguished. Ericaceous fynbos is relatively localised and rare, especially to the north, and is associated with seeps and peaty soils.

On the aridity gradient to the north on the West Coast, Ericaceae are the first to disappear, so that only FFd 5 Cape Flats Sand Fynbos and FFd 4 Atlantis Sand Fynbos retain a marked ericaceous component. Proteoids drop out next, and the restioid component is the most persistent, but diminishes as cover gets too sparse to support fire. Stands of Restionaceae persist beyond the fire margin in dune slacks where the water table prevents shrub growth by fluctuating from waterlogged in winter to rather dry in summer (and strandveld persists on the dunes and their crests). A curious exception to the role of fire in fynbos occurs in the FFd 1 Namaqualand Sand Fynbos, where Proteaceae persist on moving dune ridges, with restios in dune slacks, where sands are acidic and water tables shallow. Regeneration of proteoids occurs in deflation hollows and most populations are dominated by gnarled, senescent plants.

The boundary of sand fynbos with strandveld is a dynamic one, powered both by sparseness of the vegetation not supporting fire and by dune topography. However, the boundary is a broad one and probably relates to a diminishing return time between fires as one approaches true strandveld. The boundary is often appreciably broader, with adjacent strandveld communities dominated by succulent species, than those dominated by thicket elements. Usually thicket elements are confined to fire-safe environments of dunes, old deflation hollows and emergent rock outcrops.

A gradation occurs from proper sand fynbos inland, to transitional communities, and further to proper strandveld at the coast. The intermediate habitats are dominated by those fynbos species (chiefly Asteraceae and Restionaceae including *Elegia, Thamnochortus* and *Willdenowia* species) that are able to grow

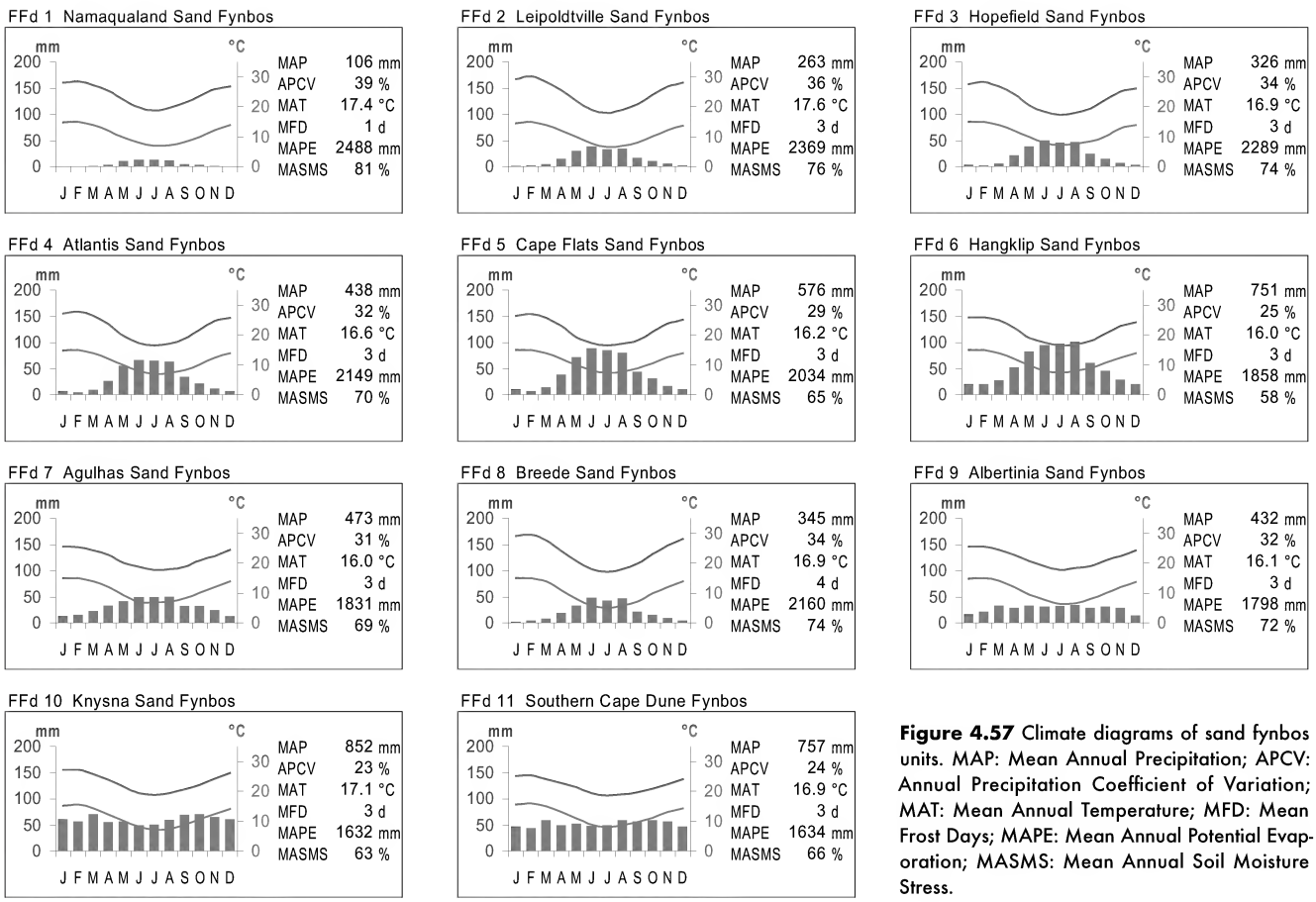


Figure 4.57 Climate diagrams of sand fynbos units. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days; MAPE: Mean Annual Potential Evaporation; MASMS: Mean Annual Soil Moisture Stress.

in very infrequently burned habitats. The margin mapped here tends to be the strandveld (coastal) end of the mosaic of intermediate communities. Fynbos stops at any dune topography, often not very prominent, which retards the spread of fire. Similarly, scarps adjacent riverine or wetland vegetation often support strandveld. Where the topography is flat, acid sands, and thus sand fynbos, may approach the beach cordon, but this is rare. The width of the ecotone from pure strandveld to pure fynbos may vary from quite abrupt to 2–5 km in certain areas. In the wider zones, several zones of transitional communities may be apparent, typically being species-poor and dominated by *Willdenowia incurvata* and a few other species (e.g. *Eriocephalus africanus*, *Wiborgia obcordata*). The strandveld boundary of these ecotone communities is more accurately mapped as adjacent succulent-dominated thicket. With thicket-dominated strandveld, fine-scale patterns may result in a mosaic with pockets of strandveld and patches of fynbos embedded in the dominant vegetation type, at a scale too fine to map.

L. Mucina

Figure 4.58 FFd 1 Namaqualand Sand Fynbos: *Leucospermum praemorsum* (Proteaceae) and restio *Willdenowia incurvata* on old inland dunes of Namaqualand Sandveld supporting relicts of fynbos, east of Hondeklipbaai (Northern Cape).

The proneness of sand fynbos to invasion by alien annual grasses—in marked contrast to other fynbos vegetation types—suggests some important, but poorly understood, ecosystem processes operating in the system. One possibility is that grazing is more important and that it is required to remove ephemeral species, especially after fire. This is paralleled by the restoration problem occurring after alien *Acacia* invaders have been removed, whereby the shrubland is effectively converted to an *Eragrostis* or *Cynodon* grassland—due to the increased nitrogen levels—preventing re-establishment of shrubs. Possibly this may relate to the relatively sedentary water table which does not flush nutrients downslope, but retains them in the system. The net effect in grazed areas is a conversion to grassland, with near-annual fires, which eliminate fynbos. In areas where fire is prevented, a stable-state grassland appears to persist and recolonisation by fynbos species from the edges is very slow (metres per fire cycle), suggesting that recruitment rather than seed availability is the problem to fynbos recolonisation.

With liming and bush-cutting, sand fynbos can be converted to pasture, especially on the South Coast, and especially on more neutral soils. Any such conversion leads to an explosion of mole rat (*Bathyergus suillus*) populations, underscoring their importance in sand fynbos and suggesting a possible key role in this system. Sand fynbos is often subject to bush-cutting and converted from proteoid fynbos to restioid fynbos by the thatching industry. Because of its low relief, sand fynbos might be expected to be heavily impacted by increased evaporation and lower rainfall when the effects of global climate change are realised.

FFd 1 Namaqualand Sand Fynbos

VT 31 Succulent Karoo (72%), VT 34 Strandveld of West Coast (24%) (Acocks 1953). LR 57 Lowland Succulent Karoo (78%) (Low & Rebelo 1996). BHU 77 Knersvlakte Vygieveld (37%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western and Northern Cape Provinces: Coastal plains with a well-separated patch between Kommagas and Koingnaas in the north, and a series of patches south of the Spoeg River, to the Olifants River near Koekenaap extending to close (around 2 km) to the coast at places, for example near Geelwal and Ruitersvlei. Altitude 60–300 m.

Vegetation & Landscape Features Slightly undulating plains comprising both isolated streets and dune fields of aeolian sand. Scattered 1–1.5 m tall shrubs 1–3 m in diameter, but dominated by Restionaceae in between, can have a dense canopy cover (50%), but is easily overgrazed to a sparse cover (20%). Restioid and asteraceous fynbos predominate, with localised pockets of proteoid fynbos. There are substantial differences between dune ridges and dune slacks, with dune slacks far more succulent, often tending to Succulent Karoo, and a much higher diversity than surrounding strandveld habitats. Ericaceae are absent, proteoids seldom numerically important, and restioids often dominant. Related to FFd 2 Leipoldtville Sand Fynbos south of the Olifants River, mainly due to the dominance of *Willdenowia incurvata* and the presence of proteoids, but Namaqualand Sand Fynbos has fewer species and less cover.

Geology & Soils Aeolian, deep, loose, red sand overlying marine or other sediments. Land types mainly Ah, Hb and Ai.

Climate Winter-rainfall regime, with very low precipitation (MAP 70–150 mm; mean: 105 mm), peaking between May and August. This is the driest of all fynbos types, with less than half the rainfall of the driest classical sand fynbos types, and almost qualifying as desert but with probably multiple alternative sources of water. Dense mists are common in winter and may contribute significantly to precipitation. Thicker deposits of sand (dunes) allow for water storage and some localised water aquifers occur. Mean daily maximum and minimum temperatures 28.4°C and 7.0°C for February and July, respectively. Very low frost incidence (1 or 2 days per year). See also climate diagram for FFd 1 Namaqualand Sand Fynbos (Figure 4.57).

Important Taxa Tall Shrubs: *Leucospermum praemorsum* (d), *L. rodolentum* (d), *Wiborgia obcordata* (d), *Gymnosporia buxifolia*. Low Shrubs: *Elytropappus rhinocerotis* (d), *Stoebe nervigera* (d), *Trichogyne repens* (d), *Chrysanthemoides incana*, *Clutia daphnoides*, *Diospyros austro-africana*, *Eriocephalus africanus* var. *africanus*, *Justicia cuneata*, *Leucadendron brunioides* var. *brunioides*, *Macrostylis decipiens*, *Metalasia adunca*, *Nenax arenicola*, *Salvia lanceolata*. Succulent Shrubs: *Othonna pro-*

tecta, *Ruschia caroli*, *R. extensa*, *R. subpaniculata*. Herbs: *Grielum grandiflorum*, *Limeum fenestratum*, *Wahlenbergia asparagoides*. Geophytic Herb: *Watsonia meriana*. Graminoids: *Ehrharta villosa* var. *villosa* (d), *Thamnochortus bachmannii* (d), *Willdenowia incurvata* (d), *Ehrharta calycina*, *Ficinia capitella*, *Ischyrolepis macer*, *I. monanthos*, *Stipagrostis zeyheri* subsp. *macropus*.

Biogeographically Important Taxa (Namaqualand endemics) Herb: *Helichrysum marmarolepis*. Succulent Herb: *Quaqua armata* subsp. *maritima*.

Endemic Taxa Succulent Shrub: *Lampranthus procumbens*. Geophytic Herbs: *Albuca decipiens*, *Babiana brachystachys*.

Conservation Least threatened. Target 29%. At present only 1% statutorily conserved (Namaqua National Park), but proclamation of the proposed new national park at the coast between the mouths of the Groen and Spoeg Rivers may extend the area under protection. About 2% has been transformed for cultivation. The area is subject to extensive sheep grazing on some farms. Aliens *Acacia cyclops* and *A. saligna* occur as scattered. Erosion very low at present, but heavy grazing can lead to remobilisation of the stabilised dunes.

L. Mucina

Figure 4.59 FFd 2 Leipoldtville Sand Fynbos: Arid proteoid fynbos with *Leucadendron pubescens* and restios dominant on deep sands near Verlorenvlei on the West Coast (Western Cape).

Remarks These dune fields are probably the leached remnants of northerly dune plumes originating from the major river mouths during pluvial periods. At the northern limits of these dune plumes dominant proteoids are usually senescent and recruitment occurs on the dunes in deflation hollows and bare areas after the death of old plants. These areas are too arid to support fire. This is the only known case of nonfire-maintained fynbos (other than waterlogged dune slacks in strandveld, where restios occur as 'sedge' communities).

References Boucher & Le Roux (1989, 1994), N. Helme (unpublished data), L. Mucina (unpublished data).

FFd 2 Leipoldtville Sand Fynbos

VT 34 Strandveld of West Coast (71%) (Acocks 1953). West Coast Strandveld (16%) (Moll & Bossi 1983). LR 68 Sand Plain Fynbos (43%), LR 64 Mountain Fynbos (25%) (Low & Rebelo 1996). BHU 10 Leipoldtville Sand Plain Fynbos (47%), BHU 83 Lamberts Bay Strandveld (15%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: On the coastal plains on either side of the Olifants River to Aurora and extending deep inland to the foot of the Graafwater Mountains and Piketberg. It also occurs in the Olifants River Valley from the Bulshoek Dam to The Baths (Keerom), with a gap between Klawer Vlei and Sandkop. Outliers are found scattered in the Swartveld from Het Kruis to the vicinity of Porterville. Altitude 50–350 m.

Vegetation & Landscape Features Plains, slightly rolling in places, covered with shrublands with an upper open stratum of emergent, 2–3 m tall shrubs in clumps. The vegetation matrix is formed by fairly dense, 1–1.2 m tall restiolands, with numerous medium tall to low shrubs scattered in between. Understorey with a conspicuous winter to spring herbaceous complement of annuals and geophytes occurs in years with good rain. Structurally, these are mainly restioid and asteraceous fynbos types, with localised patches of proteoid fynbos also present. This is a dry form of sand fynbos, lacking Ericaceae and with proteoid elements relatively rare. Sward communities, associated with grazing, are dominated by *Aizoon canariense* and *Tribolium echinatum*. At its northern (arid) boundary the sand fynbos structure becomes very diffuse and is progressively replaced by strandveld.

Geology & Soils Deep, acid, Tertiary sands, generally pale yellow to reddish brown, or grey. Land types mainly Ai, Hb, and Ca.

Climate Winter-rainfall regime with precipitation peaking from May to August. MAP 130–450 mm (mean: 260 mm). Dense mists are common in winter. Mean daily maximum and minimum temperatures 30.2°C and 6.6°C for February and July, respectively. Frost incidence 3 or 4 days per year. See also climate diagram for FFd 2 Leipoldtville Sand Fynbos (Figure 4.57).

Important Taxa Tall Shrubs: *Aspalathus acuminata* subsp. *acuminata* (d), *Leucadendron foedum* (d), *Leucadendron pubescens* (d), *Nylandtia spinosa* (d), *Aspalathus linearis*, *Chrysanthemoides monilifera*, *Diospyros glabra*, *Euclea racemosa* subsp. *racemosa*, *Euryops speciosissimus*, *Leucospermum rodolentum*, *Montinia caryophyllacea*, *Passerina corymbosa*, *Phylica paniculata*, *Wiborgia obcordata*. Low Shrubs: *Aspalathus divaricata* subsp. *divaricata* (d), *Diosma acmaeophylla* (d), *Eriocephalus africanus* var. *africanus* (d), *Passerina truncata* subsp. *truncata* (d), *Afrolimon longifolium*, *Anthospermum galioides* subsp. *galioides*, *Aspalathus ternata*, *Athanasia trifurcata*, *Metalasia adunca*, *Muraltia obovata*, *Nenax arenicola*, *Phylica cephalantha*, *P. oleaefolia*, *Rhus dissecta*[T], *Serruria fucifolia*. Succulent Shrubs: *Ruschia decurvans* (d), *Crassula nudicaulis*, *Euphorbia burmannii*. Herbs: *Senecio arenarius* (d), *Ursinia anthemoides* subsp. *anthemoides*. Geophytic Herbs: *Aristea dichotoma*, *Geissorhiza aspera*, *Lachenalia unicolor*, *Ornithogalum thyrsoides*, *Oxalis flava*. Succulent Herb: *Quaqua incarnata* subsp. *incarnata*. Graminoids: *Ehrharta calycina* (d), *Willdenowia incurvata* (d), *Cannomois scirpoides*, *Cladoraphis spinosa*, *Cynodon dactylon*, *Ischyrolepis gaudichaudiana*.

Endemic Taxa Low Shrubs: *Agathosma insignis*, *A. involucrata*, *Aspalathus rostripetala*, *Erica dregei*, *Leucadendron brunioides* var. *flumenlupinum*, *Leucospermum arenarium*, *Lotononis racemiflora*, *Manulea pillansii*, *Selago hetero-*

tricha, *S. linearifolia*. Succulent Shrubs: *Antimima triquetra*, *Drosanthemum prostratum*, *Lampranthus intervallaris*, *L. peersii*, *L. purpureus*, *L. saturatus*, *L. vernalis*, *Ruschia copiosa*, *R. maxima*, *R. victoris*. Herbs: *Adenogramma teretifolia*, *Manulea psilostoma*, *Wahlenbergia massonii*. Geophytic Herbs: *Albuca clanwilliamigloria*, *Babiana scabrifolia*, *Geissorhiza louisabolusiae*, *Pelargonium appendiculatum*, *P. attenuatum*, *P. fasciculaceum*.

L. Mucina

Figure 4.60 FFd 3 Hopefield Sand Fynbos: Restioid fynbos with scattered shrubs of *Leucadendron foedum* on deep soils, east of Hopefield (Western Cape).

Conservation Endangered. Target 29%. At present none of the unit is conserved in statutory or private conservation areas, which is alarming since 55% has already undergone transformation, including cultivation (primarily potatoes, rooibos) with central pivot irrigation, and pastures. Water extraction for central pivot irrigation and other agricultural uses is reputedly drying out this vegetation type. Alien *Acacia saligna* and *A. cyclops* are a problem. Erosion very low.

Remarks The southern boundary is not clear-cut and, being transitional, could justifiably be taken at the Berg River, the area where some elements are shared with FFd 3 Hopefield Sand Fynbos. The northern boundary is very diffuse and becomes progressively arid, gradually grading into SKs 7 Namaqualand Strandveld. Heuweltjies occur on shallower sands and support karoo shrublands (*Didelta spinosa, Rhus dissecta, Tetragonia fruticosa, Zygophyllum morgsana*).

References Milton (1978), Lane (1980), Boucher (1991, 1998d, f).

FFd 3 Hopefield Sand Fynbos

VT 47 Coastal Macchia (84%) (Acocks 1953). Sand Plain Fynbos (27%) (Moll & Bossi 1983). LR 68 Sand Plain Fynbos (88%) (Low & Rebelo 1996). BHU 11 Hopefield Sand Plain Fynbos (87%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: West Coast lowlands from Aurora to Rondeberg, just south of Yzerfontein, with an outlier in the Strandveld at Kleinberg north of Langebaanweg. Altitude 20–150 m.

Vegetation & Landscape Features Coastal sand plains, flat to undulating, and also including localised inland dune fields. Vegetation is a moderately tall, ericoid-leaved shrubland with dense herbaceous stratum of aphyllous hemicryptophytes. This is mostly asteraceous and restioid fynbos, although proteoid fynbos is extensive and ericaceous fynbos occurs in seeps and along watercourses. Hopefield Sand Fynbos has all three typical fynbos elements, but with a paucity (in species richness and density) of Ericaceae. This unit is most diverse in the Hopefield area, where extensive stands of *Leucadendron foedum, Leucospermum rodolentum* and *Serruria fucifolia* are dominant.

Geology & Soils Deep, acid, tertiary sands, generally grey regic sands, sometimes pale yellow to reddish brown. Land types mainly Hb, Ha and Db.

Climate MAP 210–430 mm (mean: 325 mm), peaking from May to August. Mists common in winter. Mean daily maximum and minimum temperatures 28.3°C and 7.1°C for February and July, respectively. Frost incidence 3 or 4 days per year. See also climate diagram for FFd 3 Hopefield Sand Fynbos (Figure 4.57).

Important Taxa Tall Shrubs: *Leucadendron foedum* (d), *Leucospermum rodolentum* (d), *Leucadendron pubescens*, *Putterlickia pyracantha*. Low Shrubs: *Diosma hirsuta* (d), *Phylica cephalantha* (d), *Anaxeton asperum*, *Anthospermum spathulatum* subsp. *spathulatum*, *Aspalathus lotoides* subsp. *lagopus*, *A. ternata*, *Erica mammosa*, *E. plumosa*, *Leucadendron cinereum*, *L. salignum*, *Leucospermum hypophyllocarpodendron* subsp. *canaliculatum*, *Metalasia capitata*, *Pharnaceum lanatum*, *Phylica harveyi*, *Serruria decipiens*, *S. fucifolia*, *Trichocephalus stipularis*. Succulent Shrub: *Euphorbia muirii*. Herbs: *Helichrysum tinctum*, *Indigofera procumbens*, *Knowltonia vesicatoria*. Geophytic Herbs: *Geissorhiza purpurascens*, *Lachenalia reflexa*, *Romulea obscura*. Graminoids: *Cannomois parviflora* (d), *Cynodon dactylon* (d), *Ehrharta villosa* var. *villosa* (d), *Elegia tectorum* (d), *Staberoha cernua* (d), *Thamnochortus erectus* (d), *T. punctatus* (d), *Willdenowia incurvata* (d), *Elegia verreauxii*.

Endemic Taxa Low Shrubs: *Leucospermum tomentosum* (d), *Relhania rotundifolia*. Herbs: *Heliophila patens*, *Lepidium flexuosum*. Geophytic Herb: *Oxalis suavis*.

Conservation Endangered. Target 30%. Very small portion statutorily conserved in the West Coast National Park, with an additional 2% protected in Hopefield and Jakkalsfontein Nature Reserves. Already 40% transformed for cultivation (especially cash crops) and grazing land. Increased occurrence of aliens such as *Acacia saligna*, *A. cyclops* as well as various species of *Pinus* and *Eucalyptus* is of concern. Erosion very low. Local farmers claim that water extraction is drying out rivers, marshes and wetlands.

Remarks The northern boundary of this unit grades into FFd 2 Leipoldtville Sand Fynbos between the Berg River and Aurora; the mapped boundary coincides with the distribution limits of most proteoid elements. On pockets of limestone, usually associated with higher relief and on the coastal edge on alkaline sands, this sand fynbos acquires strandveld elements and is replaced by FS 3 Saldanha Flats Strandveld. On the inland border, it forms mosaics with FRs 9 Swartland Shale Renosterveld as the sand thins out over the shale—most of these communities have been ploughed up for wheatlands.

References Boucher (1983, 1987, 1989a, 1996b), Boucher & Rode (1999).

FFd 4 Atlantis Sand Fynbos

VT 46 Coastal Renosterbosveld (64%) (Acocks 1953). Sand Plain Fynbos (22%) (Moll & Bossi 1983). LR 68 Sand Plain Fynbos (73%) (Low & Rebelo 1996). BHU 11 Hopefield Sand Plain Fynbos (64%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Rondeberg to Blouberg on the West Coast coastal flats; along the Groen River on the eastern side of the Dassenberg-Darling Hills through Riverlands to the area between Atlantis and Kalbaskraal, also between Klipheuwel and the Paardeberg with outliers west of the Berg River east and north of Riebeek-Kasteel between Hermon and Heuningberg. Altitude 40–250 m.

Vegetation & Landscape Features Moderately undulating to flat sand plains with a dense, moderately tall, ericoid shrubland dotted with emergent, tall sclerophyllous shrubs and an open, short restioid stratum. Restioid and proteoid fynbos are dominant, with asteraceous fynbos and patches of ericaceous fynbos in seepages.

Geology & Soils Acidic tertiary, grey regic sands, usually white or yellow. Land types mainly Db, Ha, Hb and Ca.

Climate Winter-rainfall regime with precipitation peaking from May to August. MAP 290–660 mm (mean: 440 mm). Mists (fogs) common in winter and supplying additional precipitation. Mean daily maximum and minimum temperatures 27.9°C and 7.0°C for February and July, respectively. Frost incidence about 3 days per year. See also climate diagram for FFd 4 Atlantis Sand Fynbos (Figure 4.57).

Important Taxa ([T]Cape thickets) Tall Shrubs: *Diospyros glabra*[T] (d), *Euclea racemosa* subsp. *racemosa*[T] (d), *Metalasia densa* (d), *Passerina corymbosa* (d), *Protea burchellii* (d), *P. repens* (d), *Putterlickia pyracantha*[T] (d), *Rhus laevigata*[T] (d), *Gymnosporia buxifolia*[T], *Hymenolepis parviflora*, *Wiborgia obcordata*. Low Shrubs: *Anthospermum aethiopicum* (d), *Berzelia abrotanoides* (d), *Diastella proteoides* (d), *Elytropappus rhinocerotis* (d), *Erica plumosa* (d), *Leucadendron salignum* (d), *Phylica cephalantha* (d), *Salvia lanceolata* (d), *Staavia radiata* (d), *Trichocephalus stipularis* (d), *Amphithalea ericifolia*, *Aspalathus lotoides* subsp. *lotoides*, *A. quinquefolia* subsp. *quinquefolia*, *A. ternata*, *Athanasia trifurcata*, *Cliffortia drepanoides*, *C. ferruginea*, *C. polygonifolia*, *Cryptadenia grandiflora*, *Erica ferrea*, *E. mammosa*, *Helichrysum tomentosulum*, *Hermannia alnifolia*, *Hippia pilosa*, *Lachnospermum imbricatum*, *Leonotis leonurus*, *Leucadendron cinereum*, *L. lanigerum* var. *lanigerum*, *Leucospermum hypophyllocarpodendron* subsp. *canaliculatum*, *Leysera gnaphalodes*, *Metalasia adunca*, *M. capitata*, *M. distans*, *Oedera imbricata*, *Otholobium hirtum*, *Protea acaulos*, *P. scolymocephala*, *Psoralea ensifolia*, *P. laxa*, *Rhus dissecta*[T], *Serruria decipiens*, *S. fasciflora*, *S. trilopha*. Succulent Shrub: *Crassula flava*. Woody Climbers: *Asparagus asparagoides*, *Microloma sagittatum*. Semiparasitic Shrubs: *Thesium nigromontanum* (d), *T. scabrum*. Herbs: *Annesorhiza macrocarpa*, *Arctopus echinatus*, *Castalis nudicaulis*, *Haplocarpha lanata*, *Nemesia bicornis*, *Phyllopodium cephalophorum*. Geophytic Herbs: *Aristea africana*, *Disa obtusa*, *Geissorhiza humilis*, *G. purpurascens*, *Othonna stenophylla*, *Satyrium bicorne*. Herbaceous Climber: *Cynanchum africanum*. Herbaceous Parasitic Climber: *Cassytha ciliolata*. Graminoids: *Aristida diffusa* (d), *Cannomois parviflora* (d), *Ehrharta calycina* (d), *E. villosa* var. *villosa* (d), *Ischyrolepis monanthos* (d), *Scirpoides thunbergii* (d), *Staberoha distachyos* (d), *Thamnochortus obtusus* (d), *T. punctatus* (d), *Willdenowia incurvata* (d), *W. sulcata* (d), *Cyperus textilis*, *Elegia nuda*, *Ficinia nigrescens*, *Pentaschistis curvifolia*.

Endemic Taxa Low Shrubs: *Leucospermum parile* (d), *Erica malmesburiensis*, *Serruria linearis*, *S. roxburghii*, *S. scoparia*. Herb: *Steirodiscus speciosus*.

Conservation Vulnerable. Target 30%. About 6% conserved in Riverlands, Paardenberg and at Pella Research Site. Some 40% has been transformed, mainly for cultivation (agricultural smallholdings and pastures), by urban sprawl of Atlantis and for setting up pine and gum plantations. Woody aliens include *Acacia saligna*, *A. cyclops* and various species of *Eucalyptus* and *Pinus*. Erosion very low and low.

Remark 1 This unit has greater species diversity than the sand fynbos units to the north, and exemplifies the northern limit of extensive ericaceous fynbos in sand fynbos. A record 76 species in a 5 x 10 m plot have been counted (C. Boucher, unpublished data).

Remark 2 This is probably the best researched sand fynbos type due to the location of the Pella Research Site which served as base for intensive research into fynbos ecology of the sand plain lowlands in the 1980s. Because of its history of past research (and valuable historical data), the site should be revitalised for long-term research and monitoring purposes.

L. W. Powrie

Figure 4.61 FFd 4 Atlantis Sand Fynbos: *Leucospermum parile*, endemic to the unit, dominant together with *Protea repens* surrounded by *Passerina* and *Thamnochortus* in the Pella Nature Reserve near Atlantis, Western Cape.

References Boucher (1983, 1986, 1987, 1992, 1996b), Hoffman et al. (1987), Boucher & Shepherd (1988), Jarman (1988), Jarman & Mustart (1988), Witkowski & Mitchell (1989), Musil & De Witt (1990).

FFd 5 Cape Flats Sand Fynbos

VT 47 Coastal Macchia (66%) (Acocks 1953). LR 68 Sand Plain Fynbos (85%) (Low & Rebelo 1996). BHU 12 Blackheath Sand Plain Fynbos (83%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Cape Flats from Blouberg and Koeberg Hills west of the Tygerberg Hills to Lakeside and Pelican Park in the south

L. W. Powrie

Figure 4.62 FFd 5 Cape Flats Sand Fynbos: One of the largest surviving remnants is located under power lines in the Plattekloof Natural Heritage Site, here with *Serruria aemula*, *Diastella proteoides*, *Metalasia densa* and *Passerina vulgaris*. *Thamnochortus erectus* is showing signs of senescence due to the reluctance of the managers to burn under the power lines.

near False Bay, from Bellville and Durbanville to Klapmuts and Joostenberg Hill in the east, and to the southwest of the Bottelary Hills to Macassar and Firgrove in the south. Altitude 20–200 m.

Vegetation & Landscape Features Moderately undulating and flat plains, with dense, moderately tall, ericoid shrubland containing scattered emergent tall shrubs. Proteoid and restioid fynbos are dominant, with asteraceous and ericaceous fynbos occurring in drier and wetter areas, respectively.

Geology & Soils Acid, tertiary, deep, grey regic sands, usually white, often Lamotte form. Land types mainly Ga, Hb and Db.

Climate Winter-rainfall regime with precipitation peaking from May to August. MAP 580–980 mm (mean: 575 mm). Mists occur frequently in winter. Mean daily maximum and minimum monthly temperatures 27.1°C and 7.3°C for February and July, respectively. Frost incidence about 3 days per year. This is the wettest and the coolest of the West Coast sand fynbos types. See also climate diagram for FFd 5 Cape Flats Sand Fynbos (Figure 4.57).

Important Taxa ([T]Cape thickets, [W]Wetlands) Tall Shrubs: *Metalasia densa*, *Morella cordifolia*, *M. serrata*, *Passerina corymbosa*, *Protea burchellii*, *P. repens*, *Psoralea pinnata*[W], *Pterocelastrus tricuspidatus*[T], *Rhus lucida*[T], *Wiborgia obcordata*. Low Shrubs: *Diastella proteoides* (d), *Diosma hirsuta* (d), *Erica lasciva* (d), *E. muscosa* (d), *Phylica cephalantha* (d), *Senecio halimifolius* (d), *Serruria glomerata* (d), *Stoebe plumosa* (d), *Anthospermum aethiopicum*, *Aspalathus callosa*, *A. hispida*, *A. quinquefolia* subsp. *quinquefolia*, *A. sericea*, *A. spinosa* subsp. *spinosa*, *A. ternata*, *Berzelia abrotanoides*, *Chrysanthemoides incana*, *Cliffortia eriocephalina*, *C. juniperina*, *C. polygonifolia*, *Erica articularis*, *E. axillaris*, *E. capitata*, *E. corifolia*, *E. ferrea*, *E. imbricata*, *E. mammosa*, *E. plumosa*, *E. pulchella*, *Eriocephalus africanus* var. *africanus*, *Galenia africana*, *Gnidia spicata*, *Helichrysum cymosum*, *Leucadendron floridum*, *L. salignum*, *Leucospermum hypophyllocarpodendron* subsp. *canaliculatum*, *Metalasia adunca*, *M. pulchella*, *Morella quercifolia*, *Passerina ericoides*, *Pharnaceum lanatum*, *Phylica parviflora*, *Plecostachys polifolia*, *P. serpyllifolia*, *Polpoda capensis*, *Protea scolymocephala*, *Serruria fasciflora*, *S. trilopha*, *Staavia radiata*, *Stilbe albiflora*, *Stoebe cinerea*, *Syncarpha vestita*, *Trichocephalus stipularis*. Succulent Shrub: *Crassula flava*. Herbs: *Berkheya rigida*, *Conyza pinnatifida*, *Edmondia sesamoides*, *Helichrysum tinctum*, *Indigofera procumbens*, *Knowltonia vesicatoria*. Geophytic Herbs: *Watsonia meriana* (d), *Aristea dichotoma*, *Geissorhiza tenella*, *Othonna heterophylla*, *Pelargonium longifolium*, *Wachendorfia paniculata*, *Zantedeschia aethiopica*[W]. Succulent Herb: *Carpobrotus acinaciformis*. Herbaceous Climber: *Dipogon lignosus*. Graminoids: *Cynodon dactylon* (d), *Ehrharta villosa* var. *villosa* (d), *Elegia tectorum* (d), *Restio quinquefarius* (d), *Sporobolus virginicus* (d), *Thamnochortus erectus* (d), *Willdenowia incurvata* (d), *Calopsis impolita*, *Elegia juncea*, *E. microcarpa*, *E. nuda*, *Hordeum capense*, *Hypodiscus aristatus*, *Ischyrolepis capensis*, *I. paludosa*, *Juncus capensis*, *Restio bifurcus*, *R. micans*, *R. quadratus*, *Willdenowia sulcata*, *W. teres*.

Endemic Taxa ([W]Wetlands) Low Shrubs: *Erica margaritacea* (d), *Aspalathus variegata* (probably extinct), *Athanasia capitata*, *Cliffortia ericifolia*, *Erica pyramidalis*[W], *E. turgida*, *E. verticillata*, *Leucadendron levisanus*, *Liparia graminifolia*, *Serruria aemula*, *S. foeniculacea*, *S. furcellata*. Succulent Shrub: *Lampranthus stenus*. Geophytic Herb: *Ixia versicolor*. Graminoids: *Tetraria variabilis*, *Trianoptiles solitaria*.

Conservation Critically endangered. Target 30%. Less than 1% statutorily conserved as small patches in the Table Mountain National Park as well as some private conservation areas such as Plattekloof 430 and Blaauw Mountain. This is the most transformed of the sand fynbos types—more than 80% of the area has already been transformed (hence the conservation target remains unattainable) by urban sprawl (Cape Town metropolitan area) and for cultivation. Most remaining patches are small pockets surrounded by urban areas, for example Rondevlei, Kenilworth, Milnerton, 6BKD, Plattekloof, and Rondebosch Common. Most of these patches have been identified as 'Core Conservation Sites' (Wood et al. 1994). They are mismanaged by mowing, fire protection and by alien plant invasion. Mowing eliminates serotinous and taller species, while fire protection results in a few common thicket species (e.g. *Carpobrotus edulis*, *Chrysanthemoides monilifera*), replacing the rich fynbos species. Alien woody species include *Acacia saligna*, *A. cyclops* and species of *Pinus* and *Eucalyptus*. Dumping and spread of alien grasses (both annual and *Pennisetum clandestinum*) are also a major problem. Alien acacias result in elevated nutrient levels and a conversion to *Eragrostis curvula* grassland and near-annual fires. Some 84 Red Data sand fynbos plant species occur on the remnants within Cape Town. The endemics include six species listed as extinct in the wild, some of which are being reintroduced from botanical gardens. Erosion very low.

Remark Cape Flats Sand Fynbos is richer than the other West Coast sand fynbos types, not only in Proteaceae, but also in other woody shrubs.

References Acocks (1935), Taylor (1972b), Boucher (1983, 1987, 1996b, 1997b, 1999a, g), Boshoff (1985), Wood et al. (1994), McKenzie & Rebelo (1997), Maze & Rebelo (1999a, b), Helme (2002).

FFd 6 Hangklip Sand Fynbos

VT 69 Macchia (78%) (Acocks 1953). Coastal Plain Fynbos p.p. (Boucher 1978). Mesic Mountain Fynbos (39%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (55%), LR 68 Sand Plain Fynbos (19%) (Low & Rebelo 1996). BHU 56 Kogelberg Mountain Fynbos Complex (41%), BHU 55 Cape Peninsula Mountain Fynbos Complex (31%), BHU 6 Agulhas Fynbos/Thicket Mosaic (23%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Cape Peninsula on old dune fields at Hout Bay, in the Fish Hoek gap (between Fish Hoek and Noordhoek) and on Smith's Farm (Cape Point Nature Reserve). Further on it occurs on the coastal flats from Rooiels and Cape Hangklip to Hermanus and it is well developed at the Bot River estuary. Altitude 20–150 m.

Vegetation & Landscape Features Sand dunes and sandy bottomlands supporting moderately tall, dense ericoid shrubland. Emergent, tall shrubs in places. Proteoid, ericaceous and restioid fynbos are dominant, with some asteraceous fynbos also present. On the coastal fringe this unit borders on strandveld. The deep soils of the coastal plains are replaced by shallow soils on mountain slopes on the northern edge. Hangklip Sand Fynbos occurs mainly on old dunes, but the high rainfall and leaching allows many typical sandstone fynbos species to occur on older deposits as well, so that this unit is not as floristically distinct as other sandstone fynbos units.

Geology & Soils Leached, acid Tertiary sand in coastal areas, derived mostly from dunes. Soils generally of Lamotte or Houwhoek forms or grey, regic sands. Land types mainly Ga, Hb and Gb.

Climate MAP 520–1 170 mm (mean: 750 mm), peaking from May to August. By far this is the wettest of all the sandstone fynbos types. Mean daily maximum and minimum temperatures 25.9°C and 7.5°C for January–February and July, respectively. Frost incidence about 3 days per year. See also climate diagram for FFd 6 Hangklip Sand Fynbos (Figure 4.57).

Important Taxa ([T]Cape thickets, [W]Wetlands) Tall Shrubs: *Euclea racemosa* subsp. *racemosa* (d), *Leucadendron coniferum* (d), *Metalasia densa* (d), *Passerina corymbosa* (d), *Psoralea pinnata*[W] (d), *Rhus laevigata*[T] (d), *Erica perspicua* var. *perspicua*[W], *E. tristis*, *Halleria lucida*[T], *Mimetes hirtus*, *Protea compacta*, *Pterocelastrus tricuspidatus*[T], *Rhus glauca*[T], *R. lucida*[T]. Low Shrubs: *Aspalathus nigra* (d), *Berzelia abrotanoides* (d), *Brunia alopecuroides*[W] (d), *Coleonema album* (d), *Erica mammosa* (d), *E. multumbellifera* (d), *E. muscosa* (d), *Eriocephalus africanus* var. *africanus* (d), *Osmitopsis asteriscoides*[W] (d), *Protea scolymocephala* (d), *Serruria glomerata* (d), *Adenandra viscida*, *Agathosma imbricata*, *Aspalathus forbesii*, *Berzelia lanuginosa*[W], *B. squarrosa*, *Cassine peragua* subsp. *barbara*, *Cliffortia graminea*, *Diosma hirsuta*, *Erica coccinea* subsp. *coccinea*, *E. fastigiata*, *E. patersonii*, *E. pulchella*, *Eriocephalus racemosus*, *Indigofera brachystachya*, *Leucadendron gandogeri*, *L. laureolum*, *L. salignum*, *Leucospermum hypophyllocarpodendron* subsp. *hypophyllocarpodendron*, *Metalasia pulchella*, *Mimetes cucullatus*, *Morella quercifolia*, *Orphium frutescens*[W], *Passerina ericoides*, *Pelargonium betulinum*, *P. cucullatum*, *Phylica ericoides*, *Polyarrhena reflexa* subsp. *reflexa*, *Protea cynaroides*, *Stilbe ericoides*, *Struthiola ciliata* subsp. *schlechteri*, *Trichocephalus stipularis*, *Trichogyne repens*. Succulent Shrub: *Tetragonia fruticosa*. Herbs: *Carpacoce spermacocea*, *Cineraria geifolia*. Geophytic Herbs: *Corycium bifidum*, *Geissorhiza humilis*, *Romulea triflora*, *Wachendorfia thyrsiflora*[W]. Succulent Herbs: *Carpobrotus edulis* (d), *C. acinaciformis*. Herbaceous Climber: *Cynanchum obtusifolium*. Graminoids: *Elegia filacea* (d), *E. nuda* (d), *Epischoenus gracilis* (d), *Imperata cylindrica*[W] (d), *Ischyrolepis eleocharis* (d), *Thamnochortus erectus* (d), *T. obtusus* (d), *T. spicigerus* (d), *Merxmuellera cincta*, *Staberoha cernua*, *Tetraria thermalis*.

Endemic Taxa Low Shrub: *Muraltia minuta*. Succulent Shrub: *Lampranthus serpens*. Herb: *Hypertelis trachysperma*. Geophytic Herb: *Haemanthus canaliculatus*. Graminoid: *Ischyrolepis feminea*.

Conservation Vulnerable. Target 30%. About 20% statutorily conserved in the Table Mountain National Park and Kogelberg Biosphere Reserve, with an additional 3% protected in private conservation areas such as Sea Farm and Hoek-van-die-Berg. There are several reserves between Pringle Bay and Hermanus, but they are badly mismanaged with a continual attrition of reserves with sewerage farms, graveyards, golf courses and squatters and over-harvesting of flowers and plants for oils. Some 31% has been transformed, mostly by development of holiday home settlements (coastal platform between Pringle Bay and Hermanus), but also by cultivation and building of roads. Alien woody plants include *Pinus pinaster*, *Acacia cyclops*, *A. saligna*, various *Eucalyptus* species and very many other species in localised patches. Erosion very low.

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Figure 4.63 FFd 6 Hangklip Sand Fynbos: Restioid fynbos on a narrow bypass dune above the Catholic church on Slangkop above Kommetjie on the Cape Peninsula (Western Cape), with prominent *Agathosma* (Rutaceae), *Thamnochortus* (Restionaceae) and *Othonna* (Asteraceae).

Remark 1 Pockets of *Sideroxylon*-dominated thicket and small forests occur in fire-safe hollows and dune edges, throughout the region. There are some limestone deposits associated with the old dunes, but these are localised and do not have a typical limestone fynbos community; they share species with sandstone fynbos and FS 7 Overberg Dune Strandveld.

Remark 2 Hangklip Sand Fynbos is well-sampled only in the west; there are no representative data available for patches found east of the Palmiet River.

References Adamson (1927), Boucher (1972, 1974, 1977, 1978), Taylor (1983, 1984a, b), Cowling (1991), Boix (1992), Simmons (1996), Privett (1998), Stofberg (2000).

FFd 7 Agulhas Sand Fynbos

VT 47 Coastal Macchia (98%) (Acocks 1953). Limestone Fynbos (20%) (Moll & Bossi 1983). LR 63 South and South-west Coast Renosterveld (54%), LR 67 Limestone Fynbos (23%) (Low & Rebelo 1996). BHU 15 Hagelkraal Limestone Fynbos (71%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Very fragmented patches on the Agulhas forelands from around the lower Uilkraalsrivier near Gansbaai, Hagelkraal, flats west of the Soetanysberg, small patches east of Elim to the largest patch northwest of Struisbaai, west of Arniston and south of Bredasdorp, with unmapped patches to Hermanus in the west, and De Hoop Vlei in the east. Altitude 20–100 m.

Vegetation & Landscape Features Low-lying coastal plains supporting dense moderately tall, ericoid shrubland or tall, medium dense shrubland, with some emergent tall shrubs. Communities of this fynbos unit are structurally defined either as restioid or proteoid fynbos.

Geology & Soils Neutral to acid Tertiary sands over various substrates, but most commonly over limestone of the Bredasdorp Formation. Land types mainly Db and Hb.

Climate MAP 380–660 mm (mean: 475 mm), peaking slightly in winter. Mean daily maximum and minimum temperatures 25.6°C and 7.0°C for January and July, respectively. Frost incidence about 3 days per year. See also climate diagram for FFd 7 Agulhas Sand Fynbos (Figure 4.57).

Important Taxa ([T]Cape thickets, [W]Wetlands) Tall Shrubs: *Leucadendron coniferum*, *Metalasia densa*, *Passerina corymbosa*, *Protea susannae*, *Rhus laevigata*[T]. Low Shrubs: *Amphithalea tomentosa*, *Cliffortia ferruginea*, *Elytropappus rhinocerotis*, *Erica discolor*, *E. plukenetii* subsp. *lineata*, *E. rhopalantha*, *Euchaetis burchellii*, *Leucadendron linifolium*, *Morella quercifolia*, *Orphium frutescens*[W], *Serruria nervosa*. Herb: *Senecio laevigatus*. Graminoids: *Cynodon dactylon*, *Elegia filacea*, *E. recta*, *E. tectorum*, *Hypodiscus albo-aristatus*, *Restio triticeus*, *Thamnochortus erectus*, *T. insignis*.

Endemic Taxa Low Shrubs: *Erica albertyniae*, *E. berzelioides*, *E. globulifera*, *E. interrupta*, *Lobostemon collinus*, *Wahlenbergia microphylla*. Succulent Shrubs: *Caryotophora skiatophytoides*, *Erepsia simulans*, *Lampranthus arbuthnotiae*. Graminoid: *Ficinia latifolia*.

Conservation Vulnerable. Target 32%. Some 7% statutorily conserved in the Agulhas National Park, with a further 1% found in private conservation areas such as Brandfontein, Groot Hagelkraal, Heunings River and Andrewsfield. About 27% transformed, mainly for cultivation, but alien plants (*Acacia cyclops*, *A. saligna* and *Leptospermum laevigatum*) have caused a much larger transformed area. Erosion low and very low.

Remark 1 The more alkaline communities can be arbitrarily assigned to either limestone fynbos or sand fynbos, whereas proteoid fynbos communities can be readily assigned. Some restioid and asteraceous fynbos communities are more contentious. We have defined this unit largely by *Leucadendron coniferum* in deeper sands and *L. linifolium* in seasonal vleis. The latter also occurs extensively on shallow sands over limestone that could justifiably be classified as limestone fynbos. The asteraceous fynbos communities also intergrade with FFf 1 Elim Ferricrete Fynbos.

Remark 2 This vegetation unit is more extensive than mapped, mainly within what is mapped as limestone fynbos—we lack adequate field surveys to map them accurately. The border with FFd 9 Albertinia Sand Fynbos has been chosen at about De Hoop Vlei. This boundary coincides with the easternmost *Leucadendron coniferum* (near Arniston), and the westernmost *L. eucalyptifolium*, *L. galpinii*, *Protea lanceolata* and the large form of *Leucospermum truncatum* (morphologically approaching the appearance of *L. praecox*) near Koppie Alleen.

References Van der Merwe (1977a), Cowling et al. (1988), Thwaites & Cowling (1988), Richards et al. (1995, 1997a, b), Mustart et al. (1997), Boucher (1998c).

FFd 8 Breede Sand Fynbos

VT 43 Mountain Renosterbosveld (66%), VT 26 Karroid Broken Veld (32%) (Acocks 1953). Central Mountain Renosterveld (24%), Karroid Shrublands (19%) (Moll & Bossi 1983). LR 61 Central Mountain Renosterveld (64%), LR 58 Little Succulent Karoo (26%) (Low & Rebelo 1996). BHU 26 Breede Fynbos/Renosterveld Mosaic (50%), BHU 87 Robertson Broken Veld (27%), BHU 38 Ashton Inland Renosterveld (23%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Small patches usually in close proximity to the Breede River from the Brandvlei Dam to near Robertson. Altitude 200–350 m.

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Figure 4.64 FFd 7 Agulhas Sand Fynbos: Patch of *Agathosma collina* (green shrub) within restioid fynbos dominated by *Thamnochortus insignis* in De Hoop Nature Reserve near Arniston (Western Cape).

Vegetation & Landscape Features Very fragmented, occurring as dune plumes and dune seas in the valley bottoms primarily south of the Breede River, and extending up the sides of adjacent hills. Vegetation is an open proteoid tall shrubland combined with an open to medium dense restioid herbland in undergrowth. Proteoid and restioid fynbos are dominant, with some asteraceous fynbos also found.

Geology & Soils Recent aeolian sand accumulations of riverine origin (Breede River). Land types mainly Fc, Bb and Hb.

Climate MAP 230–560 mm (mean: 345 mm), peaking from May to August. Mean daily maximum and minimum temperatures 29.6°C and 5.0°C for February and July, respectively. Frost incidence 3–6 days per year. See also climate diagram for FFd 8 Breede Sand Fynbos (Figure 4.57).

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Figure 4.65 FFd 8 Breede Sand Fynbos: *Leucadendron rodolentum* in restioid fynbos covering a slope dune near Aan de Doorns in the Breede River Valley (Western Cape).

liers near Groot Brak River and between Potberg and De Hoop Vlei. The patches of this vegetation unit almost always border a limestone fynbos type. When enclosed by limestone, it is often found in depressions which can be extensive, for example the Wankoe south of Riversdale and Canca se Leegte south of Albertinia. Altitude 20–260 m.

Vegetation & Landscape Features Plains and undulating hills with numerous dune slacks—forming the most extensive area of sand fynbos within the limestone fynbos area and occupying most of the depressions, valleys and lower slopes. Vegetation is characterised by medium tall (1.5–2 m tall) open shrub layer, together with a dense stratum of 1–1.2 m tall shrubs and hemicryptophytes. It is structurally predominantly proteoid fynbos, but with extensive restioid fynbos in the watercourses and coastal edges.

Important Taxa Tall Shrubs: *Leucospermum rodolentum* (d), *Metalasia densa*, *Protea laurifolia*. Low Shrubs: *Afrolimon longifolium*, *Aspalathus heterophylla*, *Euchaetis pungens*, *Lachnospermum fasciculatum*, *Leucadendron brunioides* var. *brunioides*, *L. salignum*, *Wiborgia fusca*. Succulent Shrub: *Ruschia caroli*. Herb: *Pelargonium senecioides*. Geophytic Herb: *Romulea setifolia*. Graminoids: *Cynodon dactylon*, *Ehrharta villosa* var. *villosa*, *Ficinia lateralis*, *Willdenowia incurvata*.

Endemic Taxon Geophytic Herb: *Ixia pumilio*.

Conservation Vulnerable. Target 30%. None of the unit conserved in statutory conservation areas and only 2% protected in the Hawequas and Quaggas Berg Private Nature Reserves. The unit enjoys conservation interest for isolated, southeasternmost populations of West Coast species. Some 45% of the area has been transformed, mainly for cultivation (pasture and vineyards) and by building of the Brandvlei and Kwaggaskloof Dams. By far the largest patch of this unit is now almost entirely under water of these reservoirs. Low levels of infestation by alien *Eucalyptus, Acacia saligna* and *Hakea sericea* have been recorded. Erosion very low and moderate, but also high in some places.

Remarks This is a poorly studied vegetation unit. Whereas most of the species are shared with FFs 13 North Sonderend Sandstone Fynbos and FFq 4 Breede Quartzite Fynbos, and a few with the South Coast FFd 9 Albertinia Sand Fynbos, it is the affinities with FFd 2 Leipoldtville Sand Fynbos that are most striking, suggesting that dunes once straddled the Hawequas Mountains, probably west of Tulbagh, allowing species to move across.

References C. Boucher (unpublished data), L. Mucina (unpublished data).

FFd 9 Albertinia Sand Fynbos

VT 47 Coastal Macchia (86%) (Acocks 1953). Limestone Fynbos (49%), Dune Fynbos (20%) (Moll & Bossi 1983). LR 67 Limestone Fynbos (53%) (Low & Rebelo 1996). BHU 17 Canca Limestone Fynbos (27%), BHU 34 Riversdale Coast Renosterveld (25%), BHU 14 Albertinia Sand Plain Fynbos (23%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Generally longitudinally east-west-trending patches on the coastal plain from Potberg in the west to the Gouritz River in the east. Also found from Kleinberg to west of Mossel Bay, with isolated unmapped out-

Geology & Soils Deep neutral to acid, usually red, Tertiary sands associated with limestone of Bredasdorp Formation, but also acid sands derived from alluvial deposits from the Gouritz River. Acid Tertiary sands, usually grey, from Potberg and Aasvogelberg are locally prominent. Land types mainly Fc, Hb and Db.

Climate MAP 230–620 mm (mean: 430 mm), with no clear peak and a slight low in December–January. Mean daily maximum and minimum temperatures 25.5°C and 6.4°C for January–February and July, respectively. Frost incidence about

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Figure 4.66 FFd 9 Albertinia Sand Fynbos: Proteoid fynbos with *Leucospermum praecox* and *Thamnochortus insignis* on deep neutral sands at Gouritzmond (Western Cape).

3 days per year. See also climate diagram for FFd 9 Albertinia Sand Fynbos (Figure 4.57).

Important Taxa ([T]Cape thickets, [W]Wetlands) Tall Shrubs: *Cassine peragua* subsp. *peragua*[T] (d), *Leucadendron eucalyptifolium* (d), *Metalasia densa* (d), *Protea repens* (d), *P. susannae* (d), *Nylandtia spinosa*, *Passerina corymbosa*, *Psoralea pinnata*[W]. Low Shrubs: *Chironia baccifera* (d), *Cliffortia ilicifolia* (d), *C. stricta* (d), *Erica imbricata* (d), *Lachnaea axillaris* (d), *Agathosma bifida*, *A. scaberula*, *Amphithalea tomentosa*, *Anthospermum prostratum*, *Aulax umbellata*, *Carpacoce vaginellata*, *Chrysocoma ciliata*, *Cliffortia drepanoides*, *Diospyros dichrophylla*[T], *Erica discolor*, *E. pulchella*, *E. sessiliflora*, *E. versicolor*, *Euryops ericoides*, *Leucadendron meridianum*, *L. salignum*, *Muraltia ciliaris*, *Passerina galpinii*, *P. rigida*, *Phylica parviflora*, *Psoralea laxa*, *Senecio ilicifolius*, *Staavia radiata*, *Struthiola ciliata* subsp. *incana*, *Syncarpha paniculata*, *Trichocephalus stipularis*, *Trichogyne repens*. Herbs: *Edmondia sesamoides*, *Senecio laevigatus*. Geophytic Herbs: *Pteridium aquilinum* (d), *Bobartia robusta*, *Bulbine frutescens*, *Romulea dichotoma*, *R. gigantea*[W]. Graminoids: *Calopsis adpressa* (d), *Elegia stipularis* (d), *Ischyrolepis leptoclados* (d), *Mastersiella purpurea* (d), *Thamnochortus insignis* (d), *Cynodon dactylon*, *Elegia muirii*, *E. tectorum*, *Mastersiella spathulata*, *Staberoha distachyos*, *Thamnochortus erectus*, *T. fruticosus*, *Willdenowia teres*.

Endemic Taxa Tall Shrubs: *Leucospermum praecox* (d), *Leucadendron galpinii* (d), *Leucospermum fulgens*. Low Shrubs: *Euchaetis albertiniana* (d), *Agathosma pallens*, *Aspalathus acutiflora*, *A. dasyantha*, *A. odontoloba*, *A. quadrata*, *A. sanguinea* subsp. *foliosa*, *Diosma sabulosa*, *Erica baueri* subsp. *baueri*, *E. dispar*, *E. viscosissima*, *Lebeckia fasciculata*, *Leucospermum muirii*, *Lobelia valida*. Succulent Shrubs: *Lampranthus antemeridianus*, *L. creber*, *L. diutinus*, *L. fergusoniae*, *L. multiseriatus*. Herb: *Zaluzianskya muirii*. Graminoid: *Thamnochortus muirii*.

Conservation Vulnerable. Target 32%. About 5% statutorily conserved in De Hoop, Pauline Bohnen, Geelkrans, Kleinjongensfontein, Skulpiesbaai and Blomboschfontein Nature Reserves, with an additional 2% protected in private conservation areas such as Rein's Coastal (Gouriqua) Nature Reserve, Die Duine etc. Some 26% transformed for cultivation (pasture) and pine plantations, but a large proportion has also been transformed by alien plants (*Acacia cyclops* and *A. saligna*). In addition, large areas have been converted from proteoid fynbos to restioid fynbos by bush-cutting for thatching. Erosion very low.

Remark 1 The boundary between the limestone and sand fynbos is often one of soil depth, with limestone fynbos being largely confined to skeletal soils. In permanently wet areas and fire-safe habitats, thicket may occur, often in association with *Protea lanceolata*, *Elegia microcarpa* and *Thamnochortus erectus*—these are usually at the interface between sand and limestone fynbos. *Leucospermum muirii* is an endemic to the grey, sandstone-derived soils—it is not known whether other endemics to this soil type occur or whether this deserves special recognition.

Remark 2 This unit is still not accurately mapped and is more extensive than shown. Pockets occur in valleys and depressions within limestone fynbos as far west as De Hoop Vlei and as far east as the Groot Brak River. Disturbed areas on the coastal fringe sometimes converted to *Cynodon* grazing, with extensive mole rat (*Bathyergus suillus*) activity.

Remark 3 The tall tussock restios typical of this sand fynbos are an important source for the thatching industry.

References Muir (1929), Rebelo et al. (1991), Boucher (1995, 1997d, 1998c), Boucher & Rode (1995a, b).

FFd 10 Knysna Sand Fynbos

VT 4 Knysna Forest (85%) (Acocks 1953). LR 2 Afromontane Forest (72%), LR 4 Dune Thicket (24%) (Low & Rebelo 1996). BHU 100 Knysna Afromontane Forest (72%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Garden Route coastal flats from Wilderness, generally to the north of the system of lakes, several patches around the Knysna Lagoon, with more isolated patches eastwards to the Robberg peninsula near Plettenberg Bay. Altitude 40–300 m.

Vegetation & Landscape Features Undulating hills and moderately undulating plains covered with a dense, moderately tall, microphyllous shrubland, dominated by species more typical of sandstone fynbos.

Geology & Soils Deep, acid Tertiary sand inland of coastal dunes forming regic sands and soils of Lamotte form. Land types mainly Hb and Ga.

Climate MAP 670–1 090 mm (mean: 850 mm), with a slight peak in autumn and spring. Mean daily maximum and minimum temperatures 27.3°C and 7.3°C for February and July, respectively. Frost incidence 2 or 3 days per year. See also climate diagram for FFd 10 Knysna Sand Fynbos (Figure 4.57).

Important Taxa Small Tree: *Widdringtonia nodiflora*. Tall Shrubs: *Cliffortia linearifolia*, *Leucadendron eucalyptifolium*, *Metalasia densa*, *Passerina corymbosa*. Low Shrubs: *Anthospermum aethiopicum*, *Berzelia intermedia*, *Cliffortia drepanoides*, *Clutia rubricaulis*, *Erica diaphana*, *E. glandulosa* subsp. *fourcadei*, *E. glumiflora*, *E. sessiliflora*, *Helichrysum asperum* var. *asperum*, *Lachnaea diosmoides*, *Leucadendron salignum*, *Leucospermum cuneiforme*, *Lobelia coronopifolia*, *Morella quercifolia*, *Muraltia squarrosa*, *Oedera imbricata*, *Protea cynaroides*, *Stoebe plumosa*, *Tephrosia capensis*. Herbs: *Geranium incanum*, *Helichrysum felinum*. Graminoids: *Aristida junciformis* subsp. *galpinii*, *Brachiaria serrata*, *Cynodon dactylon*, *Eragrostis capensis*, *Ficinia bulbosa*, *Heteropogon contortus*, *Ischyrolepis eleocharis*, *Tetraria cuspidata*, *Thamnochortus cinereus*, *Themeda triandra*, *Tristachya leucothrix*.

Conservation Endangered. Target 23%. Patches are statutorily conserved in the proposed Garden Route National Park (about 3%) as well as 2% in several private nature reserves. Almost 70% already transformed (pine and gum plantations, cultivation, Knysna urban sprawl, building of roads). Alien *Acacia melanoxylon, A. mearnsii* and *A. longifolia* occur locally at low densities. Erosion very low and moderate.

Remark This is a very poorly researched vegetation unit.

References Taylor (1970b), Drews (1980a).

FFd 11 Southern Cape Dune Fynbos

Psammophilous Macchia (Phillips 1931). VT 70 False Macchia (51%) (Acocks 1953). Maritime Heath (Martin & Noel 1960). South Coast Dune Fynbos (Cowling 1984). Mosaic of Dune Fynbos & Kaffrarian Thicket (79%) (Moll & Bossi 1983). Dune Fynbos (Lubke & Van Wijk 1988). LR 4 Dune Thicket (82%) (Low & Rebelo 1996). BHU 9 St Francis Fynbos/Thicket Mosaic (39%), BHU 8 Goukamma Fynbos/Thicket Mosaic (38%) (Cowling et al. 1999b, Cowling & Heijnis 2001). STEP Goukamma Dune Thicket (46%), STEP St. Francis Dune Thicket (10%), STEP Kiwane Dune Thicket p.p. (Vlok & Euston-Brown 2002, Vlok et al. 2003).

Distribution Western and Eastern Cape Provinces: Two large mapped patches on the Indian Ocean Coast span the Wilderness Estuary and Buffels Bay near Knysna (Western Cape), and Tsitsikamma River mouth to Oyster Bay (Eastern

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Figure 4.67 FFd 11 Southern Cape Dune Fynbos: Steep slope of leached sand dune at the edge of the Alexandria Dunefield supporting dense *Olea exasperata* fynbos near Alexandria (Eastern Cape).

Cape). Smaller cordons occur further east between Oyster and St Francis Bays. A series of smaller unmapped patches occur as far west as Mossel Bay and eastwards to near East London. Altitude 20–220 m.

Vegetation & Landscape Features Coastal dune cordons (those towering above the Groenvlei near Sedgefield considered the tallest vegetated dunes in southern Africa) often with steep slopes. The vegetation is fynbos heath dominated by sclerophyllous shrubs with a rich restio undergrowth. The dominant shrubs include *Olea exasperata* and *Phylica litoralis*, while among restios *Ischyrolepis eleocharis* is most prominent. The relatively recent (last 100 years) exclusion of fire from a large percentage of this unit enabled many woody species to displace the fynbos vegetation. The alien *Acacia cyclops* often acted as a precursor for the establishment of thicket vegetation in sites where fynbos or coastal dunes used to occur. These thicket clumps occurring within this dune fynbos are not rich in species and have *Pterocelastrus tricuspidatus, Rhus lucida, Sideroxylon inerme* and *Tarchonanthus littoralis* as the dominant species.

Geology & Soils Stabilised old calcareous or neutral dunes (some as old as 120 000 years) outside the influence of salt spray built of deep sands, moving in places. Soils of Lamotte form, main land types Hb and Ga.

Climate MAP 600–900 mm (mean: 757 mm), with a slight peak in autumn and spring. Mean daily maximum and minimum temperatures 25.3°C and 8.0°C for February and July, respectively. Frost is a rare phenomenon due to the strong marine influence of the ocean. See also climate diagram for FFd 11 Southern Cape Dune Fynbos (Figure 4.57).

Important Taxa Tall Shrubs: *Olea exasperata* (d), *Passerina corymbosa*, *Rhus crenata*, *R. glauca*, *R. laevigata*, *R. lucida*. Low Shrubs: *Agathosma ovata* (d), *Metalasia muricata* (d), *Passerina rigida* (d), *Phylica litoralis* (d), *Agathosma apiculata*, *A. stenopetala*, *Anthospermum aethiopicum*, *Aspalathus spinosa* subsp. *spinosa*, *Chironia baccifera*, *Erica fourcadei*, *E. glumiflora*, *E. zeyheriana*, *Felicia echinata*, *Gnidia anthylloides*, *Helichrysum teretifolium*, *Indigofera sulcata*, *Jamesbrittenia microphylla*, *Leucadendron salignum*, *Morella quercifolia*, *Muraltia saturei-oides*, *M. squarrosa*, *Otholobium bracteolatum*, *Pelargonium betulinum*, *Phylica ericoides*, *Polygala ericaefolia*, *Struthiola parviflora*. Semiparasitic Shrub: *Thesidium fragile*. Geophytic Herbs: *Satyrium princeps* (d). *Cyrtanthus loddigesianus*, *C. obliquus*. Graminoids: *Ischyrolepis eleocharis* (d), *Ehrharta calycina*, *Ficinia dunensis*, *Ischyrolepis leptoclados*, *Pentaschistis heptamera*, *Tetraria cuspidata*, *Thamnochortus cinereus*, *Tribolium obtusifolium*.

Endemic Taxa Low Shrubs: *Aspalathus cliffortiifolia* (possibly extinct), *Erica chloroloma*. Succulent Shrub: *Lampranthus algoensis*. Graminoids: *Pentaschistis barbata* subsp. *orientalis*.

Conservation Least threatened. Target 36%. More than 16% statutorily conserved in the Goukamma (housing the most prominent examples of this vegetation unit) and Huisklip Nature Reserves as well as in the proposed Garden Route National Park. An additional 4% is protected in private conservation areas such as Thyspunt, Rebelsrus and Klasies River Cave. About 17% has been transformed, mainly for cultivation, plantations and by urban development. Dense stands of alien *Acacia cyclops* and *A. saligna* are of conservation concern and are being targeted for removal. *A. mearnsii* and *Leptospermum laevigatum* also occur in places. Erosion very low and low.

Remarks Taylor & Morris (1981) made an explicit link between (coastal) 'Grassland' and 'Calcrete Fynbos' and claimed that the balance between these two is a delicate one, being controlled by the depth of soil (hence nutrient status) as well as by degree of grazing and trampling. According to local farmers in the Port Elizabeth area, fire is supposed to be of minor importance. Cowling & Pierce (1985) observed that in areas with pronounced summer rainfall, the dune fynbos is almost entirely replaced by grasslands dominated by *Themeda triandra, Stenotaphrum secundatum* and species of *Cymbopogon*. They suggested that the dune fynbos would extend along the eastern seaboards of South Africa as far north as KwaZulu-Natal. Indeed the elements of coastal dune fynbos representing geographically outlying taxa of the genera *Metalasia* (*M. muricata*), *Passerina* (*P. corymbosa, P. rigida*), *Morella* (*M. quercifolia*), *Phylica* (*P. ericifolia*) etc. occur along those coastal stretches on exposed dune slopes and crests. This narrow belt thins out towards the north to become only few metres broad on the KwaZulu-Natal coast. A report by Vlok & Euston-Brown (2002; see their description of the Kiwane Dune Thicket) supplies further thoughts about the link between coastal grasslands and coastal fynbos. *Acmadenia kiwanensis* (at present considered by us as endemic to AT 9 Albany Coastal Belt) may be an indicator of former transformations of this fynbos-grassland complex.

References Phillips (1931), Martin & Noel (1960), Van der Merwe (1976), Taylor & Morris (1981), Cowling (1982, 1983d, 1984), Olivier (1983), Cowling & Pierce (1985, 1988), Lubke & Van Wijk (1988), Hanekom et al. (1989), Lubke & De Villiers (1991), Vlok & Euston-Brown (2002), Vlok et al. (2003), D. Hoare (unpublished data), L. Mucina (unpublished data).

9.1.4 Shale Fynbos

Shale fynbos occurs in areas with leached soils derived from shale. It is almost always found at higher altitudes, usually on southern slopes abutting the mountains. Most shale fynbos units (except those associated with the inland Witteberg Quartzite) abut granite fynbos and share many of their species

with it. In many high-rainfall areas, the shales are covered by silcrete and ferricrete, dealt with as separate vegetation units. Shale fynbos is the forth largest group of fynbos types and comprises 5% of the area of fynbos.

Floristically and structurally the shale fynbos is very similar to granite fynbos, except that it lacks the rocky outcrops and boulders typical of granite fynbos and thus lacks the scrub forest and thicket elements. The much smoother terrain results in a far more uniform landscape, with seeps and slopes generating most habitat heterogeneity. In proteoid fynbos in the Western Cape, *Protea coronata* and *P. lepidocarpodendron* are more prominent than in granite fynbos. There is a preponderance of grasses, with graminoid fynbos being prominent, especially in the eastern units of shale fynbos.

Shale fynbos grades into shale renosterveld on lower slopes and in drier areas. Shale fynbos has been poorly studied and it is not known how the interface between frequent fires (every 2–5 years) in renosterveld and rarer fires (15–30 years) typical of fynbos varies across the two vegetation types. Presumably shale fynbos burns on an intermediate cycle and may form the zone in which the apparently disparate fire regimes intergrade. Too frequent burning can convert shale fynbos to grassland (and often used for pasture), especially when coupled with bush-cutting, liming and the introduction of aggressive pasture grasses.

A prominent feature of shale fynbos is the abundance of grasses and herbs in the early seral stages. In the wettest areas the fire ephemerals may become 1 m tall in the first spring—dying back after three to four years, and the asteraceous and proteoid components then begin to dominate the vegetation. Shale fynbos in the winter-rainfall area is very dense when mature, with tall proteoids in the overstorey, and a dense understorey of ericoids. In the more even-rainfall areas, the mature veld is typically a dense, low shrubland with prominent grassy elements.

The current structural classification (Campbell 1985) for shale and silcrete fynbos types is inadequate. Most key out as mesotrophic asteraceous fynbos, primarily because low (< 1.5 m) serotinous proteas do not feature in the key. However, the recognition of key species (*Leucadendron elimense, L. globosum, L. laxum, L. modestum, L. teretifolium, L. stelligerum*) as characteristic taxa of mesotrophic proteoid fynbos is required for these fynbos types. Waboomveld—characterised by *Protea nitida*—is curiously lacking in certain units within this type. Where present, *P. nitida* is often found as the dwarf form resprouting at the base, or occurs in screes which possibly provide some fire protection, although this species is remarkably fire-resistant elsewhere.

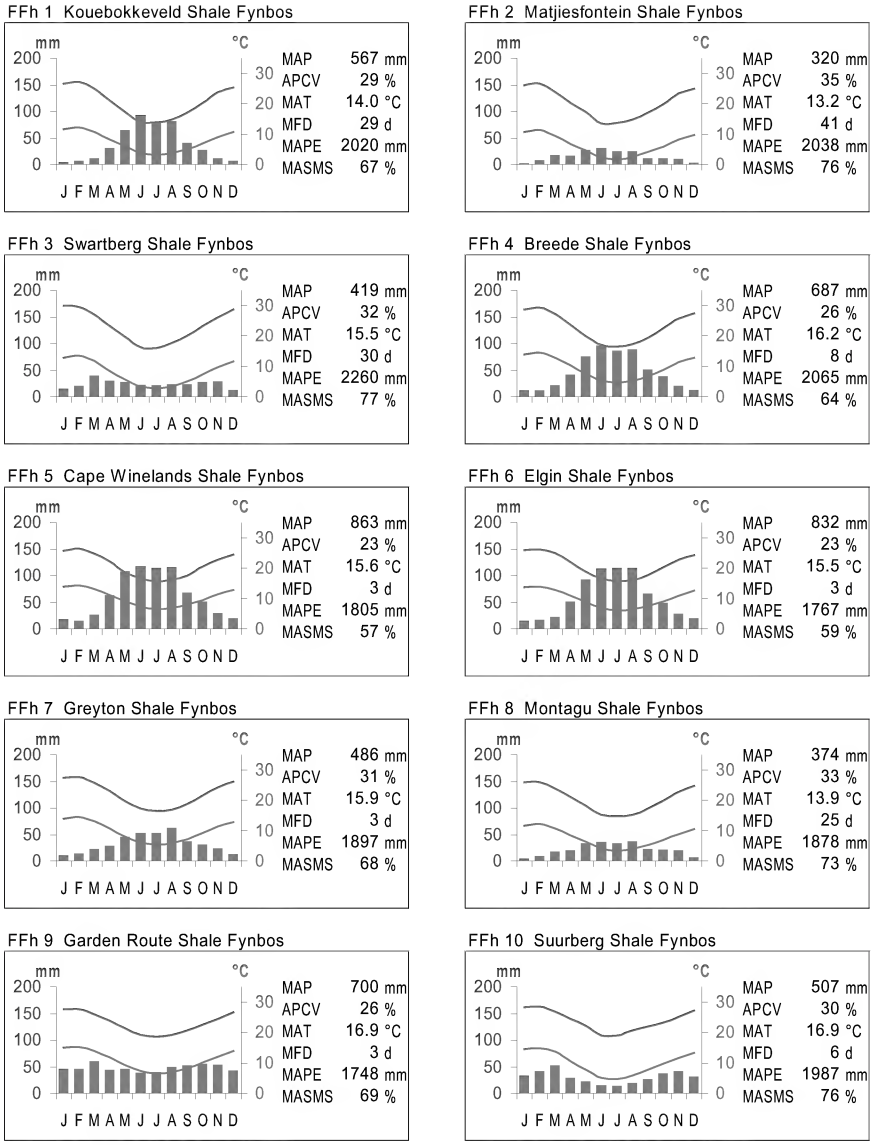

Figure 4.68 Climate diagrams of shale fynbos units. Blue bars show the median monthly precipitation. The upper and lower red lines show the mean daily maximum and minimum temperature respectively. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days (days when screen temperature was below 0°C); MAPE: Mean Annual Potential Evaporation; MASMS: Mean Annual Soil Moisture Stress (% of days when evaporative demand was more than double the soil moisture supply).

FFh 1 Kouebokkeveld Shale Fynbos

VT 69 Macchia (89%) (Acocks 1953). Mesic Mountain Fynbos (42%), Central Mountain Renosterveld (8%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (67%) (Low & Rebelo 1996). BHU 49 Swartruggens Mountain Fynbos Complex (44%), BHU 37 Waveren-Bokkeveld Inland Renosterveld (26%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Koue Bokkeveld Valley from Waboomrivier and Rosendal (Koue Bokkeveld) to Gydo Pass (north of Ceres), edge of the Warm Bokkeveld from Gydo Pass along the lower slopes of the Gydoberg and Waboomberg to the upland plateau with Klondyke and Muilbergsvlakte, and Agter Witzenberg valleys, from Rosendal (Swartruggens) to Wakkerstroom. Altitude 900–1 100 m.

Vegetation & Landscape Features Slightly undulating plains and steep slopes in valleys between high mountains, supporting mainly moderately tall and dense proteoid shrubland. Asteraceous, proteoid and waboomveld fynbos shrublands are dominant, with fynbos restiolands occurring in the bottomlands.

Geology & Soils Acidic, moist clay-loam prismacutanic or pedocutanic soils,

L. Mucina

Figure 4.69 FFh 1 Kouebokkeveld Shale Fynbos: Waboomveld with *Protea nitida* on the Gydo Pass, north of Ceres (Western Cape).

derived from Bokkeveld Shales. Land types mainly Db, Fb, Fa, Bb and Ib.

Climate MAP 300–920 mm (mean: 570 mm). Mean daily maximum and minimum temperatures 27.1°C and 3.1°C for February and July, respectively. Frost incidence 10–30 days per year. See also climate diagram for FFh 1 Kouebokkeveld Shale Fynbos (Figure 4.68).

Important Taxa ([W]Wetlands) Small Tree: *Protea nitida* (d). Tall Shrubs: *Leucadendron rubrum*, *Montinia caryophyllacea*, *Protea laurifolia*, *P. repens*. Low Shrubs: *Acmadenia matroosbergensis*, *Anthospermum aethiopicum*, *Aspalathus alpestris*, *A. desertorum*, *A. intricata* subsp. *intricata*, *A. lanifera*, *A. nudiflora*, *Cliffortia ruscifolia*, *Elytropappus rhinocerotis*, *Lachnaea pedicellata*, *Leucadendron salignum*, *Phylica odorata*. Geophytic Herbs: *Geissorhiza geminata*[W], *G. ornithogaloides* subsp. *marlothii*, *Romulea minutiflora*, *R. setifolia*, *R. tortuosa*. Graminoids: *Pentaschistis colorata*, *P. eriostoma*, *Themeda triandra*.

Endemic Taxa Low Shrubs: *Aspalathus compacta*, *Erica florifera*. Succulent Shrub: *Lampranthus lewisiae*. Geophytic Herbs: *Geissorhiza silenoides*, *Moraea variabilis*.

Conservation Endangered. Target 29%. No statutory reserves, but almost 20% protected in the Koue Bokkeveld (mountain catchment area) and private nature reserves such as Wakkerstroom and Opdrag. About 40% has been transformed, mostly for fruit orchards and grazing land, with large areas of seeps and lower areas converted to farm dams. North of Gydo Pass it is largely transformed, so that the remaining areas are not representative of the vegetation type. Alien *Pinus radiata* occurs occasionally. Erosion very low and moderate.

Remarks This is a poorly studied vegetation type. The listed taxa are not representative of the diversity in this type, since most of the accessible landscape has been transformed. In the east it is predominantly grassy, whereas in the west the proteas form a dense overstorey.

Reference Campbell (1985).

FFh 2 Matjiesfontein Shale Fynbos

VT 70 False Macchia (99%) (Acocks 1953). Central Mountain Renosterveld (66%) (Moll & Bossi 1983). LR 61 Central Mountain Renosterveld (78%) (Low & Rebelo 1996). BHU 62 Witteberg Mountain Fynbos Complex (67%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Very fragmented unit on the higher peaks of mountain ranges in the extreme western Little Karoo south of Witberg from Suurberg (southeast of Touws River) to Ezelsfontein (southwest of Laingsburg). Confined to summits and southern slopes. Altitude 1 000–1 500 m.

Vegetation & Landscape Features Gentle and steep southern slopes south of quartzitic outcrops, covered by moderately tall and dense proteoid shrubland. This vegetation is primarily asteraceous and proteoid (mesotrophic) fynbos.

Geology & Soils Acidic, moist clay-loam, red-yellow apedal or skeletal soils derived from shales of the Devonian Witteberg Group, and associated with quartzitic outcrops. Land types mainly Ic and Ah.

Climate MAP 210–470 mm (mean: 320 mm), peaking from May to August. Mean daily maximum and minimum temperatures 26.5°C and 1.7°C for February and July, respectively. Frost incidence 20–40 days per year. The most arid of shale fynbos types, probably only maintained by runoff from quartzite fynbos and cool nocturnal temperatures. Occurring at well below the usual rainfall limits for fynbos on shale. See also climate diagram for FFh 2 Matjiesfontein Shale Fynbos (Figure 4.68).

Important Taxa Tall Shrubs: *Protea repens* (d), *Leucadendron pubescens*, *L. rubrum*, *Protea laurifolia*, *P. punctata*. Low Shrubs: *Aspalathus intricata* subsp. *intricata*, *Cliffortia ruscifolia*, *Elytropappus rhinocerotis*, *Euryops imbricatus*, *Leucadendron barkerae*, *L. brunioides* var. *brunioides*, *L. cadens*, *L. salignum*, *L. teretifolium*, *Leucospermum wittebergense*, *Passerina obtusifolia*, *Protea canaliculata*, *P. humiflora*, *P. lorifolia*, *P. revoluta*, *P. scolopendriifolia*, *P. sulphurea*, *Relhania relhanioides*, *R. tri-*

L. Mucina

Figure 4.70 FFh 2 Matjiesfontein Shale Fynbos: Dry restioid fynbos with scattered shrubs of *Protea laurifolia* on the Farm Elandsfontein at the southern foot of the Witteberge near Touwsrivier.

cephala, *Spatalla confusa*, *Vexatorella obtusata* subsp. *albomontana*. Graminoids: *Hypodiscus neesii*, *H. sulcatus*, *Pentaschistis eriostoma*.

Conservation Least threatened. Target 27%. Almost 30% statutorily conserved in the Anysberg Nature Reserve in the eastern part of its distribution area. The western portion does not enjoy any formal protection. About 3% transformed for cultivation. Erosion low and very low.

Remarks A very poorly studied vegetation type, requiring detailed study. It shares many species with FFq 3 Matjiesfontein Quartzite Fynbos, but often contains far more grasses. It grades into renosterveld, which covers all the northern slopes and most of the bottomlands on shales within the landscape.

References Vlok (2002), N. Helme (unpublished data).

FFh 3 Swartberg Shale Fynbos

VT 70 False Macchia (82%) (Acocks 1953). South Coast Renosterveld (58%) (Moll & Bossi 1983). LR 63 South and South-west Coast Renosterveld (56%) (Low & Rebelo 1996). BHU 43 Kango Inland Renosterveld (93%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: A very fragmented unit from the southern foothills of the Klein and Groot Swartberge, occurring in isolated pockets from the vicinity of Ladismith to Matjiesrivier and north of the Groot Swartberge around Gideonshoop southwest of Klaarstroom. Altitude 650–1 150 m.

Vegetation & Landscape Features Steep to gentle slopes below sandstone mountains, supporting moderately tall and dense shrublands, structurally classified as asteraceous and proteoid (mesotrophic) fynbos.

Geology & Soils Acidic, moist clay-loam, Glenrosa or Mispah forms derived from shales of the Bokkeveld Group (Devonian) and the Cango Group (Namibian Erathem). Land types mainly Fc, Fb and Ib.

Climate MAP 230–780 mm (mean: 420 mm), with no clear peak and a slight low from December to February. Mean daily maximum and minimum temperatures 29.9°C and 2.6°C for January and July, respectively. Frost incidence 10–30 days per year. See also climate diagram for FFh 3 Swartberg Shale Fynbos (Figure 4.68).

Important Taxa ([T]Cape thickets) Small Tree: *Protea nitida* (d). Succulent Tree: *Aloe ferox*. Tall Shrubs: *Phylica paniculata* (d), *Protea repens* (d), *Dodonaea viscosa* var. *angustifolia*, *Leucadendron rubrum*, *Protea eximia*, *P. punctata*, *Rhus lucida*[T]. Low Shrubs: *Protea lorifolia* (d), *Anthospermum aethiopicum*, *Elytropappus rhinocerotis*, *Leucadendron barkerae*, *L. salignum*, *Leucospermum cuneiforme*, *L. wittebergense*, *Metalasia pulcherrima* f. *pallescens*, *Mimetes cucullatus*, *Oedera genistifolia*, *Paranomus dispersus*, *Passerina obtusifolia*, *Ursinia heterodonta*. Geophytic Herb: *Cheilanthes eckloniana*. Graminoids: *Brachiaria serrata*, *Cannomois scirpoides*, *Cymbopogon pospischilii*, *Hypodiscus striatus*, *H. synchroolepis*, *Rhodocoma fruticosa*, *Themeda triandra*, *Willdenowia teres*.

Conservation Least threatened. Target 27%. Statutorily conserved in the Groot Swartberg (9%) and Klein Swartberg Nature Reserves (3%). About 12% of the area has been transformed, mostly for cultivation. Erosion very low and low.

Remark This is a poorly studied vegetation unit, confined to the higher foothills of the Swartberg, mostly as transition to renosterveld.

References Bond (1981), N. Helme (unpublished data).

FFh 4 Breede Shale Fynbos

VT 69 Macchia (83%) (Acocks 1953). Central Mountain Renosterveld (36%), Mesic Mountain Fynbos (31%) (Moll & Bossi 1983). LR 61 Central Mountain Renosterveld (65%) (Low & Rebelo 1996). BHU 37 Waveren-Bokkeveld Inland Renosterveld (52%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Breede River and Slanghoek Valleys discontinuously from Tulbagh (Winterhoek 'Kom') to Swellendam, on the lower southern slopes of the Groot Winterhoek, Witsenberg, Hex and Langeberg Mountains and at places along the base of the Slanghoekberge and western Badsberg. Altitude 150–750 m, with pockets up to 900 m.

Vegetation & Landscape Features Steep upper slopes below mountains grading to slightly undulating plains, well dissected by rivers. Vegetation is a moderately tall and dense shrubland—mostly restioid, proteoid and asteraceous (mesotrophic) fynbos. A remarkably tall and dense post-fire component dominates early seral communities on wetter slopes.

Geology & Soils Acidic, moist clay-loam, Glenrosa or Mispah forms derived from Bokkeveld Shales, underlain by rocks of the Malmesbury Group. Land types mainly Fa, Fb and Ic.

Climate Winter-rainfall climate with MAP 300–1 300 mm (mean: 690 mm), peaking from May to August. Mean daily maximum and minimum temperatures 29.2°C and 4.6°C for February and July, respectively. Frost incidence 3–10 days per year. See also climate diagram for FFh 4 Breede Shale Fynbos (Figure 4.68).

Important Taxa Small Tree: *Protea nitida* (d). Tall Shrubs: *Cliffortia serpyllifolia* (d), *Dodonaea viscosa* var. *angustifolia* (d), *Leucadendron eucalyptifolium*

L. Mucina

Figure 4.71 FFh 3 Swartberg Shale Fynbos: Asteraceous fynbos with scattered *Protea nitida* and undergrowth rich in asteraceous shrubs such as *Metalasia pulcherrima, Ursinia heterodonta* and various species of *Oedera, Relhania* and *Athanasia* north of Ladismith on southern slopes of the Klein Swartberg Mountains (Western Cape).

(d), *L. rubrum*, *Protea burchellii*, *P. laurifolia*, *P. neriifolia*, *P. repens*. Low Shrubs: *Aspalathus spinosa* subsp. *spinosa* (d), *Cliffortia ruscifolia* (d), *Elytropappus rhinocerotis* (d), *Erica hispidula* (d), *E. versicolor* (d), *Oedera squarrosa* (d), *Penaea cneorum* subsp. *ruscifolia* (d), *Stoebe cinerea* (d), *Aulax cancellata*, *Erica pubigera*, *Eriocephalus africanus* var. *africanus*, *Felicia filifolia* subsp. *filifolia*, *Leucadendron salignum*, *L. spissifolium* subsp. *spissifolium*, *Passerina obtusifolia*, *Pteronia paniculata*. Succulent Shrubs: *Ruschia caroli* (d), *Adromischus filicaulis* subsp. *filicaulis*, *Erepsia gracilis*, *Tetragonia fruticosa*. Herb: *Edmondia sesamoides*. Geophytic Herb: *Lanaria lanata* (d). Graminoids: *Tetraria flexuosa* (d), *Capeobolus brevicaulis*, *Cymbopogon marginatus*, *Ehrharta ramosa* subsp. *ramosa*, *Ischyrolepis capensis*, *I. curviramis*, *I. gaudichaudiana*, *Rhodocoma fruticosa*, *Tetraria ustulata*.

L. Mucina

Figure 4.72 FFh 5 Cape Winelands Shale Fynbos: Proteaceous fynbos dominated by *Protea coronata, Leucadendron sessile* and *Leucospermum gueinzii* on shale slopes below the Helderberg Mountain (Western Cape).

Endemic Taxa Low Shrubs: *Rafnia angulata* subsp. *thunbergii*, *Vexatorella latebrosa*. Succulent Shrubs: *Drosanthemum opacum*, *Lampranthus dregeanus*, *L. tulbaghensis*, *Oscularia vernicolor*. Geophytic Herb: *Oxalis lindaviana*.

Conservation Vulnerable. Target 30%. About 30% conserved in Cape Nature and other statutory nature reserves such as Grootwinterhoek Wilderness Area, Dassieshoek, Marloth, Wittebrug and Witzenberg and in mountain catchment areas such as Langeberg-wes, Matroosberg and Winterhoek. About 30% of the area is transformed, mostly for cultivation. *Pinus pinaster* and *Hakea sericea* are the most serious woody aliens in the unit. Erosion very low and moderate.

Remark This is a very poorly studied vegetation unit.

References Chesselet (1985), Boschoff (1989), McDonald (1993b).

FFh 5 Cape Winelands Shale Fynbos

VT 69 Macchia (81%) (Acocks 1953). Mesic Mountain Fynbos (53%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (61%), LR 62 West Coast Renosterveld (27%) (Low & Rebelo 1996). BHU 32 Boland Coast Renosterveld (39%), BHU 54 Franschhoek Mountain Fynbos Complex (28%), BHU 56 Kogelberg Mountain Fynbos Complex (18%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Higher hills and lower mountain slopes in the Stellenbosch and Somerset West areas, in patches from Blousteen on Clarence Drive at Koeëlbaai to south of Elsenberg and within the Jonkershoek Valley, with pockets on the Cape Peninsula at Devils Peak, the Tygerberg Hills on Kanonkop, Groenberg near Wellington and the upper Franschhoek Valley. Altitude 0–700 m.

Vegetation & Landscape Features Moderately undulating plains and steep slopes against the mountains. Vegetation is a moderately tall and dense shrubland dominated by proteoid and closed-scrub fynbos in structural terms.

Geology & Soils Acidic, moist clay-loamy, red-yellow apedal and Glenrosa and Mispah forms derived from Malmesbury Shales. Land types mainly Ac, Fa and Ic.

Climate MAP 520–1 690 mm (mean: 865 mm), peaking from May to August. This is the shale fynbos unit with the highest rainfall. Mean daily maximum and minimum temperatures 26.4°C and 6.6°C for February and July, respectively. Frost incidence 2 or 3 days per year. See also climate diagram for FFh 5 Cape Winelands Shale Fynbos (Figure 4.68).

Important Taxa ([T]Cape thickets, [W]Wetlands) Small Trees: *Kiggelaria africana*[T], *Leucadendron argenteum*, *Leucospermum conocarpodendron* subsp. *viridum*, *Protea nitida*. Tall Shrubs: *Aspalathus uniflora* (d), *Cliffortia cuneata* (d), *C. phillipsii* (d), *Halleria lucida*[T] (d), *Maytenus acuminata*[T] (d), *Myrsine africana*[T] (d), *Olea europaea* subsp. *africana*[T] (d), *Protea coronata* (d), *P. repens* (d), *Rhus angustifolia*[T] (d), *Chrysanthemoides monilifera*, *Cunonia capensis*[T], *Diospyros glabra*[T], *Metalasia densa*, *Protea lepidocarpodendron*, *Rhus tomentosa*[T]. Low Shrubs: *Aspalathus cephalotes* subsp. *violaceae* (d), *Brunia nodiflora* (d), *Cliffortia polygonifolia* (d), *C. ruscifolia* (d), *Cullumia ciliaris* (d), *C. setosa* (d), *Erica equisetifolia* (d), *E. hirta* (d), *E. hispidula* (d), *E. nudiflora* (d), *E. parviflora*[W] (d), *Leucadendron sessile* (d), *L. spissifolium* subsp. *spissifolium* (d), *Stoebe cinerea* (d), *Anthospermum aethiopicum*, *A. spathulatum* subsp. *spathulatum*, *Aspalathus lebeckioides*, *Elytropappus gnaphaloides*, *E. rhinocerotis*, *Erica paniculata*, *Eriocephalus africanus* var. *africanus*, *Helichrysum pandurifolium*, *H. teretifolium*, *Leucadendron salignum*, *Maytenus oleoides*[T], *Protea acaulos*, *P. lorea*, *P. scabra*, *Salvia africana-caerulea*, *Senecio pubigerus*, *Stoebe plumosa*. Geophytic Herbs: *Bobartia indica* (d), *Mohria caffrorum* (d), *Pteridium aquilinum* (d), *Watsonia borbonica* subsp. *borbonica* (d), *Aristea cantharophila*, *A. capitata*, *Babiana villosula*, *Micranthus junceus*, *Romulea rosea*. Herbaceous Parasitic Climber: *Cassytha ciliolata*. Graminoids: *Cannomois virgata* (d), *Ehrharta ramosa* subsp. *ramosa* (d), *Elegia juncea* (d), *Ficinia oligantha* (d), *F. trichodes* (d), *Ischyrolepis capensis* (d), *I. gaudichaudiana* (d), *Merxmuellera stricta* (d), *Pentaschistis colorata* (d), *P. eriostoma* (d), *Restio triticeus* (d), *Schoenoxiphium lanceum* (d), *Staberoha cernua* (d), *Tetraria cuspidata* (d), *Ehrharta calycina*, *Ficinia indica*.

Endemic Taxon Geophytic Herb: *Moraea aristata*.

Conservation Endangered, but well conserved. Target 30% already reached since about 25% is statutorily conserved in the Table Mountain National Park, Helderberg and Hottentots Holland Nature Reserves. An additional 25% enjoys protection in mountain catchment areas (Hottentots Holland, Hawequas). The rest of the area has been transformed, mainly for pine

plantations and vineyards as well as by urban development of the Cape Town metropolitan area. Essentially only the steeper upper portions remain. The notable woody aliens include *Pinus pinaster* and *Hakea sericea*. Erosion very low.

Remarks This is a poorly studied vegetation type. Vegetation should be subjected to detailed analysis. This type may occur in FFb 2 Western Coastal Shale Band Vegetation but in this region the shale band occurs at altitudes (500–1 500 m) well above that typical of the vegetation described for this unit. Many species are shared with the FFg 3 Peninsula Granite Fynbos and include several local endemics (e.g. *Leucadendron argenteum*, *L. daphnoides, Leucospermum grandiflorum, L. gueinzii, Serruria kraussii*).

References Andrag (1970), Anonymous (1979), Lamprecht (1979), Boucher (1983, 1987), Swart (1983), Lötter & Van Wageningen (1988), Raitt (1999), N. Helme (unpublished data), L. Mucina (unpublished data).

FFh 6 Elgin Shale Fynbos

VT 69 Macchia (98%) (Acocks 1953). Mesic Mountain Fynbos (17%) (Moll & Bossi 1983). LR 63 South and South-west Coast Renosterveld (75%), LR 64 Mountain Fynbos (24%) (Low & Rebelo 1996). BHU 25 Elgin Fynbos/ Renosterveld Mosaic (39%), BHU 33 Overberg Coast Renosterveld (21%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Elgin Basin east of Grabouw and Villiersdorp Basin around Vyeboom, with pockets to the north at the uppermost part of Stettynskloof, Kaaimansgat and Rooihoogte Pass, and at the Steenbras Dam to the west. Altitude 200–450 m.

Vegetation & Landscape Features Undulating hills and moderately undulating plains and steep slopes of adjacent mountains. An open to medium dense tall proteoid shrubland over a matrix of moderately tall and dense evergreen shrubs, dominated by proteoid, asteraceous and closed-scrub fynbos, and ericaceous fynbos in the wetter facies.

Geology & Soils Acidic, moist clay-loam, Glenrosa or Mispah forms derived from Bokkeveld Group shales. Land types mainly Fa.

Climate Winter-rainfall regime, with MAP 560–1 300 mm (overall mean: 830 mm), peaking from May to August. Mean daily maximum and minimum temperatures 26.2°C and 6.2°C for February and July, respectively. Frost incidence 2 or 3 days per year. See also climate diagram for FFh 6 Elgin Shale Fynbos (Figure 4.68).

Important Taxa ([T]Cape thickets) Tall Shrubs: *Cliffortia cuneata*, *Freylinia longiflora*, *Leucadendron salicifolium*, *Protea coronata*, *P. lepidocarpodendron*, *P. repens*, *Rhus angustifolia*[T], *R. rehmanniana*[T]. Low Shrubs: *Erica quadrangularis* (d), *Anthospermum spathulatum* subsp. *saxatile*, *Aspalathus millefolia*, *A. nigra*, *A. nudiflora*, *Brunia laevis*, *B. neglecta*, *Cliffortia apiculata*, *C. atrata*, *Elytropappus rhinocerotis*, *Erica bruniifolia*, *E. plukenetii* subsp. *plukenetii*, *E. setacea*, *E. sphaeroidea*, *E. viscaria* subsp. *longifolia*, *Helichrysum cymosum*, *H. patulum*, *Hermannia grossularifolia*, *Leucadendron laureolum*, *L. salignum*, *L. xanthoconus*, *Nenax acerosa*, *Otholobium rotundifolium*, *Phylica spicata*, *Printzia polifolia*, *Protea longifolia*, *P. scabra*. Herbs: *Berkheya herbacea*, *Corymbium africanum*, *Peucedanum strictum*. Geophytic Herbs: *Aristea cantharophila*, *Bobartia indica*, *Geissorhiza inflexa*, *Micranthus junceus*, *Oxalis compressa*. Graminoids: *Askidiosperma rugosum*, *Ehrharta calycina*, *Elegia stipularis*, *Festuca caprina*, *Ficinia indica*, *Ischyrolepis capensis*, *Merxmuellera rufa*, *M. stricta*, *Tetraria bromoides*, *Themeda triandra*, *Tribolium brachystachyum*.

Endemic Taxa Low Shrubs: *Leucadendron elimense* subsp. *vyeboomense*, *L. globosum*.

Conservation Critically endangered. The target of 30% is double that of the remaining natural distribution. Some patches of the unit are statutorily conserved in the Theewaters and Limietberg Nature Reserves. The privately owned Solva Farm (near Grabouw) has probably the best preserved patch of this rare fynbos type. Almost 80% of the areas have been transformed, with cultivation accounting for almost 60% (mainly fruit orchards, pine plantations and the flooded area of the Theewaterskloof and Steenbras Dams). This region is characterised by very intensive and profitable agricultural land. Aliens *Pinus pinaster* and *Hakea sericea* are problems in the remaining remnants. Erosion very low.

Remarks Many of the remnants are too small to burn regularly and diversity in the stands is declining. This is the only winter-rainfall shale fynbos type with extensive ericaceous fynbos. Amongst the shale fynbos types, this unit has few succulents. This type may occur in FFb 2 Western Coastal Shale Band Vegetation, but in this region the shale band occurs at altitudes (500–1 500 m) well above that typical of the vegetation described for this unit.

References Boucher (1977, 1978), Rode (1994), N. Helme (unpublished data).

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Figure 4.73 FFh 6 Elgin Shale Fynbos: Proteoid fynbos dominated by *Protea repens* and *Leucadendron elimense* subsp. *vyeboomensis* near Vyeboom, south of Villiersdorp (Western Cape).

FFh 7 Greyton Shale Fynbos

VT 69 Macchia (64%) (Acocks 1953). Dry Mountain Fynbos (30%), South West Coast Renosterveld (27%) (Moll & Bossi 1983). LR 63 South and South-west Coast Renosterveld (63%), LR 64 Mountain Fynbos (37%) (Low & Rebelo 1996). BHU 18 Genadendal Grassy Fynbos (72%), BHU 33 Overberg Coast Renosterveld (20%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: South of Riviersonderend and Caledon Swartberg Mountains on higher-altitude

L. Mucina

Figure 4.74 FFh 7 Greyton Shale Fynbos: Proteoid fynbos with *Leucadendron salignum* and *Protea repens* (and scattered alien *Hakea sericea* and *Pinus pinaster*, in the background) on shale slopes below a sandstone ridge south of Genadendal (Western Cape).

shales from Theewaterskloof Dam to Stormsvlei, including the Bergfontein and Spitskop hills north of Caledon. Altitude 200–550 m.

Vegetation & Landscape Features Moderately undulating plains and steep slopes of adjacent mountains. The vegetation is a moderately tall and dense shrubland, predominantly proteoid and asteraceous fynbos, with some graminoid fynbos.

Geology & Soils Acidic, moist clay-loam and colluvium with various, often Glenrosa and Mispah forms, derived from Bokkeveld Group shales, often with Ordovician sandstones of the Table Mountain Group (Cape Supergroup). Land types mainly Fa, Fb and Db.

Climate Rainfall peaks slightly in winter (August high). MAP 320–710 mm (mean: 485 mm). Mean daily maximum and minimum temperatures 27.6°C and 5.4°C for February and July, respectively. Frost incidence 2 or 3 days per year. See also climate diagram for FFh 7 Greyton Shale Fynbos (Figure 4.68).

Important Taxa Small Tree: *Protea nitida*. Tall Shrubs: *Leucadendron salicifolium* (d), *Protea neriifolia* (d), *P. repens* (d), *P. aurea* subsp. *aurea*, *P. coronata*. Low Shrubs: *Clutia tomentosa*, *Elytropappus rhinocerotis*, *Erica cruenta*, *E. paniculata*, *E. peltata*, *E. vestita* (pink form), *Helichrysum petiolare*, *Leucadendron salignum*, *L. spissifolium* subsp. *spissifolium*, *L. teretifolium*, *Muraltia capensis*, *Paranomus dispersus*, *Printzia polifolia*, *Protea acaulos*, *P. lorea*, *P. restionifolia*, *P. scabra*, *Serruria acrocarpa*, *S. gremialis*, *S. zeyheri*. Herb: *Corymbium cymosum*. Geophytic Herbs: *Aristea cantharophila*, *Bobartia longicyma* subsp. *longicyma*, *Geissorhiza inflexa*, *Ixia longituba* var. *bellendenii*, *Tritoniopsis elongata*. Graminoids: *Merxmuellera stricta*, *Themeda triandra*.

Endemic Taxa Low Shrubs: *Podalyria orbicularis*, *P. reticulata*. Semiparasitic Shrub: *Thesium micropogon*. Geophytic Herbs: *Aristea biflora*, *Moraea atropunctata*, *M. insolens*.

Conservation Vulnerable. Target 30%. Only 1% statutorily conserved in the Riviersonderend Nature Reserve with an additional 6% enjoying protection in a private conservation area of the same name. Some 30% of the area already transformed, mostly for cultivation. Lower-lying areas are the most heavily converted. Woody aliens include *Hakea sericea*, various *Pinus* species and *Acacia cyclops*. Erosion very low and moderate.

Remarks This is a poorly researched vegetation unit. Amongst the shale fynbos types, it has few succulents.

Reference N. Helme (unpublished data).

FFh 8 Montagu Shale Fynbos

VT 70 False Macchia (45%), VT 43 Mountain Renosterbosveld (23%) (Acocks 1953). Central Mountain Renosterveld (60%), Karroid Shrublands (23%) (Moll & Bossi 1983). LR 61 Central Mountain Renosterveld (63%), LR 58 Little Succulent Karoo (22%) (Low & Rebelo 1996). BHU 41 Montagu Inland Renosterveld (63%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: A fragmented unit from the western Little Karoo at relatively high altitudes north of the Langeberg Mountains from Keerom to Langkloof east of Garcia's Pass (north of Riversdale). Includes parts of The Koo, Ouberg Pass area (between Montagu and Ladismith), Kleinberg (MontEco) and Wildehondskloofhoogte (between Montagu and Barrydale). Altitude 680–1 150 m.

Vegetation & Landscape Features Moderately undulating uplands and undulating foothills to steep mountains, supporting moderately tall and dense shrublands, with proteoid fynbos and asteraceous fynbos with scattered proteoid emergents. Localised waboomveld also occurs.

D. Gwynne-Evans

Figure 4.75 FFh 8 Montagu Shale Fynbos: Asteracecous fynbos on shale in the Koo Valley east of Montagu (Western Cape) in the rainshadow of the Langeberg. A group of planted *Eucalyptus* is in the background.

Geology & Soils Acidic, moist clay-loamy Glenrosa and Mispah forms derived from Bokkeveld Group shales. Land types mainly Fc and Fb.

Climate Rainfall at the edge of semi-aridity, with MAP 240–800 mm (mean: 375 mm), peaking slightly in winter. Mean daily maximum and minimum temperatures 25.9°C and 3.4°C for January–February and July, respectively. Frost incidence 10–30 days per year. See also climate diagram for FFh 8 Montagu Shale Fynbos (Figure 4.68).

Important Taxa Small Tree: *Protea nitida*. Tall Shrubs: *Protea laurifolia* (d), *P. neriifolia* (d), *P. repens* (d), *Dodonaea viscosa* var. *angustifolia*, *Lebeckia cytisoides*, *Leucadendron rubrum*. Low Shrubs: *Athrixia heterophylla* subsp. *heterophylla*, *Cliffortia ramosissima*, *Elytropappus rhinocerotis*, *Leucadendron salignum*, *L. teretifolium*, *Leucospermum calligerum*, *Protea humiflora*, *P. lorifolia*, *P. scolopendriifolia*, *P. sulphurea*, *Senecio pinifolius*, *Ursinia heterodonta*, *Vexatorella obtusata* subsp. *obtusata*. Geophytic Herbs: *Geissorhiza ornithogaloides* subsp. *marlothii*, *Ixia leipoldtii*, *Romulea sphaerocarpa*, *Wurmbea compacta*. Graminoids: *Ehrharta calycina*, *E. capensis*, *Ischyrolepis capensis*, *Karroochloa purpurea*, *Tribolium hispidum*.

Biogeographically Important Taxon Geophytic Herb: *Ixia gloriosa* (Little Karoo endemic).

Endemic Taxa Low Shrubs: *Amphithalea pageae*, *Aspalathus rostrata*, *Lotononis argentea*, *Stirtonanthus insignis*.

Conservation Least threatened. Target 30%. Conserved in the Garcia Nature Reserve and Langeberg-wes mountain catchment area. Some 15% transformed for cultivation. Alien *Pinus pinaster* and *Acacia cyclops* scattered in some areas. Erosion high in most of the unit, but very low in some areas.

Remark This is an almost unknown vegetation unit, revealed only recently by the Protea Atlas Project activities—another type well below lower rainfall limits of about 600 mm for shale fynbos.

Reference Protea Atlas Project (unpublished data).

FFh 9 Garden Route Shale Fynbos

VT 4 Knysna Forest (58%) (Acocks 1953). Mesic Mountain Fynbos (17%), South Coast Renosterveld (17%), Afro-Montane Forest (16%) (Moll & Bossi 1983). LR 2 Afromontane Forest (46%), LR 64 Mountain Fynbos (27%) (Low & Rebelo 1996). BHU 100 Knysna Afromontane Forest (41%), BHU 28 Blanco Fynbos/Renosterveld Mosaic (21%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western and Eastern Cape Provinces: Patches along the coastal foothills of the Langeberg at Grootberg (northeast of Heidelberg), the Outeniqua Mountains from Cloete's Pass via the Groot Brak River Valley, Hoekwil, Karatara, Barrington and Knysna to Plettenberg Bay. Patches from the Bloukrans Pass along coastal platform shale bands south of the Tsitsikamma Mountains via Kleinbos and Fynboshoek to south of both Clarkson and the Kareedouw Mountains. Altitude 0–500 m.

Vegetation & Landscape Features Undulating hills and moderately undulating plains on the coastal forelands. Structurally this is tall, dense proteoid and ericaceous fynbos in wetter areas, and graminoid fynbos (or shrubby grassland) in drier areas. Fynbos appears confined to flatter more extensive landscapes that are exposed to frequent fires—most of the shales are covered with afrotemperate forest. Fairly wide belts of *Virgilia oroboides* occur on the interface between fynbos and forest. Fire-safe habitats nearer the coast have small clumps of thicket, and valley floors have scrub forest (Vlok & Euston-Brown 2002).

Geology & Soils Acidic, moist clay-loam, prismacutanic and pedocutanic soils derived from Caimans Group and Ecca (in the east) shales. Land types mainly Db and Fa.

Climate MAP 310–1 120 mm (mean: 700 mm), relatively even throughout the year, but with a slight low in winter. Mean daily maximum and minimum temperatures 27.6°C and 6.5°C for January and July, respectively. Frost incidence 2 or 3 days per year. See also climate diagram for FFh 9 Garden Route Shale Fynbos (Figure 4.68).

Important Taxa ([T]Cape thickets) Tall Shrubs: *Leucadendron eucalyptifolium* (d), *Protea aurea* subsp. *aurea* (d), *P. coronata* (d), *Leucospermum formosum*, *Metalasia densa*, *Passerina corymbosa*, *Protea neriifolia*, *Rhus lucida*[T]. Low Shrubs: *Acmadenia alternifolia*, *A. tetragona*, *Anthospermum aethiopicum*, *Cliffortia ruscifolia*, *Elytropappus rhinocerotis*, *Erica hispidula*, *Helichrysum cymosum*, *Leucadendron salignum*, *Pelargonium cordifolium*, *Phylica axillaris*, *P. pinea*, *Psoralea monophylla*, *Selago corymbosa*. Herb: *Helichrysum felinum*. Geophytic Herbs: *Pteridium aquilinum* (d), *Eriospermum vermiforme*. Succulent Herb: *Crassula orbicularis*. Herbaceous Succulent Climber: *Crassula roggeveldii*. Graminoids: *Ischyrolepis sieberi* (d), *Aristida junciformis* subsp. *galpinii*, *Brachiaria serrata*, *Cymbopogon marginatus*, *Elegia juncea*, *Eragrostis capensis*, *Ischyrolepis gaudichaudiana*, *Restio triticeus*, *Themeda triandra*, *Tristachya leucothrix*.

Endemic Taxa Geophytic Herbs: *Cyphia georgica*, *Disa newdigateae*, *Gladiolus roseovenosus*.

Conservation Endangered. Target 23%. Statutorily conserved in the proposed Garden Route National Park (4%) and Boosmansbos Wilderness Area (1%). A further 3% are protected in other (mainly private) conservation areas such as the Robbe Hoek Forest Reserve. More than half of the area has already been transformed for cultivation and pine plantations. Much of the remaining veld has been converted to pasture. Remnants are found largely on steep inclines and in areas unsuitable for agriculture. Alien plants such as *Hakea sericea* and various species of *Acacia* locally infest natural remnants. Erosion very low and moderate.

Remarks This is a poorly studied vegetation type. Rebelo et al. (1991) have incorrectly placed this unit on sandstone in the Riversdale area.

References Taylor (1970b), Drews (1980a, b), Rebelo et al. (1991), Vlok & Euston-Brown (2002).

FFh 10 Suurberg Shale Fynbos

VT 70 False Macchia (64%) (Acocks 1953). Valley Bushveld (61%) (Moll & Bossi 1983). LR 65 Grassy Fynbos (42%), LR 6 Xeric Succulent Thicket (37%) (Low & Rebelo 1996). BHU 23 Zuurberg Grassy Fynbos (19%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Eastern Cape Province: East-west-trending, complex and multiple bands from the Klein Winterberg at Baroe in the west, Suurberg, and highly fragmented distributions around Riebeek East and Grahamstown. Altitude 400–900 m.

Vegetation & Landscape Features Low mountains or hills, supporting low to medium high, closed, ericoid shrubland or grassland, with closed restioid and/or grass understorey. Graminoid fynbos, with localised patches of dense proteoid fynbos, also occurs.

L. Mucina

Figure 4.76 FFh10 Suurberg Shale Fynbos: Ericaceous fynbos on ridges of the Suurberg Mountains north of Addo (Eastern Cape). Patches of afrotemperate forest are found in the gullies.

Geology & Soils Acidic, moist clay-loam Mispah and Glenrosa forms derived from Witteberg Group shales, associated with quartzite. Land types mainly Fa, Ib and Fb.

Climate MAP 210–770 mm (mean: 510 mm), with a bimodal peak in October–November and January–February and a low in winter. Mean daily maximum and minimum temperatures 28.4°C and 4.6°C for February and July, respectively. Frost incidence 2–10 days per year. See also climate diagram for FFh 10 Suurberg Shale Fynbos (Figure 4.68).

Important Taxa ([T]Cape thickets) Tall Shrubs: *Aspalathus setacea* (d), *Metalasia densa* (d), *Montinia caryophyllacea*, *Phylica paniculata*, *Protea lorifolia*, *Rhus lucida*. Low Shrubs: *Selago corymbosa* (d), *Agathosma ovata, Diospyros dichrophylla*[T], *Elytropappus rhinocerotis*, *Erica thamnoides*, *Felicia filifolia* subsp. *filifolia*, *Leucadendron salignum*, *Leucospermum cuneiforme*, *Metalasia pungens*, *Protea cynaroides*, *P. foliosa*. Succulent Shrub: *Cotyledon orbiculata* var. *oblonga*. Geophytic Herbs: *Bobartia orientalis* subsp. *orientalis*, *Oxalis punctata*. Graminoids: *Themeda triandra* (d), *Diheteropogon filifolius*, *Ehrharta ramosa* subsp. *ramosa*, *Harpochloa falx*, *Hypodiscus striatus*, *Restio triticeus*, *Tetraria cuspidata*, *T. exilis*, *Tristachya leucothrix*.

Conservation Least threatened. Target 23%. About 40% statutorily conserved in the Greater Addo Elephant National Park, and 6% in addition in the private Rockdale Game Ranch and Kuzuko Game Reserve. Only about 1% has been transformed and levels of alien infestation (*Acacia mearnsii*, species of *Eucalyptus* and *Pinus pinaster*) are low. Erosion very low and low.

Remark Few studies have separated the quartzite from the shale fynbos types in the Eastern Cape and therefore the distinction we suggest is tentative, pending detailed studies.

References Martin & Noel (1960), Jessop & Jacot Guillarmod (1969), Campbell (1985).

9.1.5 Fynbos Shale Band Vegetation

Between the two massive sandstone blocks (Peninsula and Nardouw Formations) in the Table Mountain Group (Cape Supergroup) lies a series of only 40–140 m wide shale bands (vertical) of the Cedarberg Formation. Despite their limited spatial extent, they are a major topographical feature in the mountains due to special geomorphological features (smoother landscape) and vegetation quite distinct from that of the surrounding sandstones, although sandstone overburden on the shales can blur distinctions in places. Because the bands weather preferentially, they form 20–500 m steps or shelves in horizontal beds or smooth U-valleys in more vertical beds, extending for hundreds of kilometres (Figure 4.78). The exposed shale width varies depending on its erosion at the lower edge and on sandstone-derived screes and deposits (colluvial sediments) on the upper edge. However, because the rainfall limits for the succulent karoo, renosterveld, fynbos and forest are higher for shale than sandstone, different vegetation types often occur juxtaposed on the two substrates. Where fynbos occurs on both geologies almost invariably different structural fynbos units juxtapose. Due to a lack of studies, we have been unable to separate these different communities within the shale bands other than to note that they are distinct from the surrounding sandstone fynbos communities and—based on the studies to date—from more extensive shale communities as well. We therefore predict that at lower altitudes these communities will resemble nearby shale communities (renosterveld, succulent karoo), but with increasing altitude these communities will become more unique and less associated with neighbouring vegetation types irrespective of substrate. The uppermost shale band will have altimontane fynbos.

Important microclimatic differences were found between soils derived from sandstone and shale at high altitude by Boelhouwers (1998). His measurements made in the Hex River Mountains (at an altitude of about 1 900 m) suggested that while the porous and light-coloured sandstone-derived soils failed to provide evidence for needle-ice formation, the high water content in the loamy soil derived from shale was favourable for needle-ice formation during the freeze/thaw cycles from April to November.

Patterns of vegetation on the shale bands are complicated by the sandstone colluvium and mixing of this with clays from the shale bands. Shale bands often show signs of silcrete and ferricrete formation. More important, though, is that the shale bands are relatively impervious to water and so often become associated with seep communities, often much wetter and waterlogged than those on the associated sandstones. It is possible then that the shale bands of the Cedarberg Formation are refugia for renosterveld elements and those shale fynbos communities that tolerate a much wetter climate than at present.

Based on patterns within fynbos, we have divided them tentatively into six major geographical units, based primarily on the known phytogeographic centres of endemism (Goldblatt & Manning 2000a). This is entirely an interim classification and we expect that when sufficient data become available, the larger area of these units to be subsumed into the current vegetation types within Succulent Karoo, shale renosterveld and shale fynbos. A few new high-altitude shale fynbos types might be warranted.

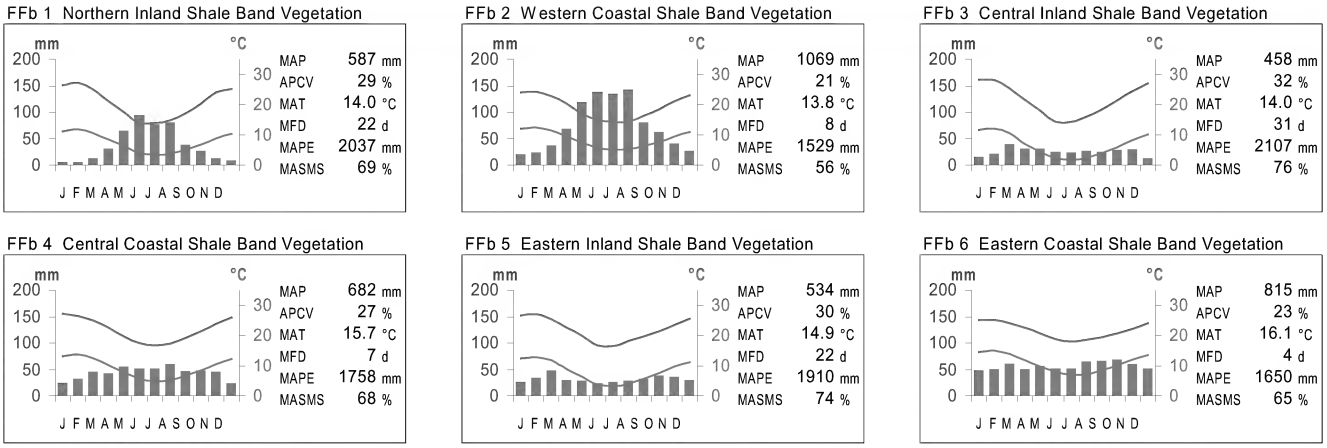

Figure 4.77 Climate diagrams of shale band vegetation units. Blue bars show the median monthly precipitation. The upper and lower red lines show the mean daily maximum and minimum temperature respectively. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days (days when screen temperature was below 0°C); MAPE: Mean Annual Potential Evaporation; MASMS: Mean Annual Soil Moisture Stress (% of days when evaporative demand was more than double the soil moisture supply).

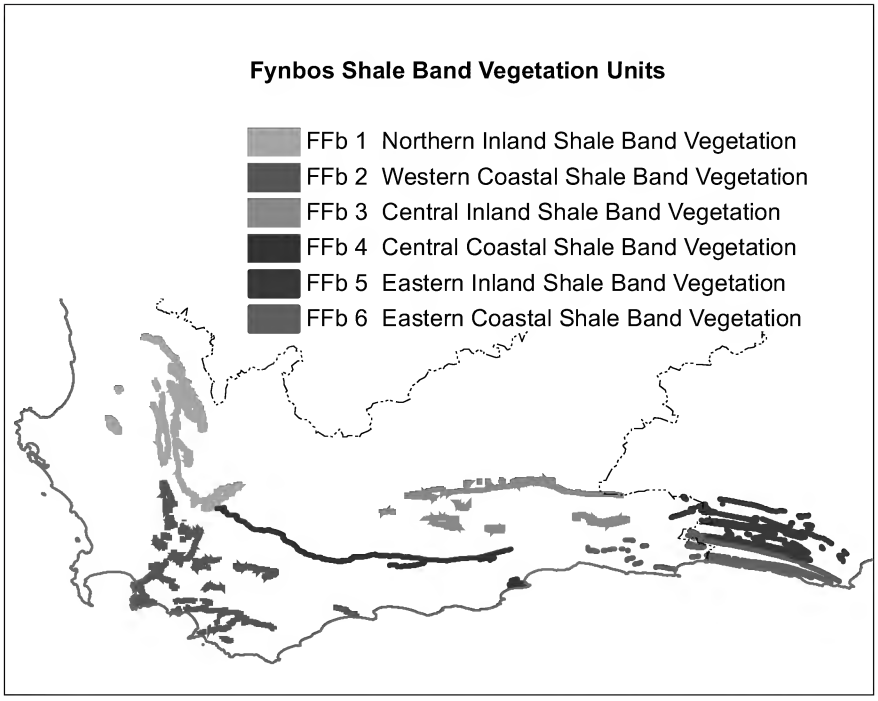

Figure 4.78 Schematic map of the shale-band vegetation units (FFb) in the Fynbos Biome.

FFb 1 Northern Inland Shale Band Vegetation

VT 69 Macchia (Fynbos) (97%) (Acocks 1953). Mesic Mountain Fynbos (94%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (100%) (Low & Rebelo 1996). BHU 47 Cederberg Mountain Fynbos Complex (53%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Narrow shale band from Mount Synnott near the Pakhuis Pass in the Cederberg, to the Skurweberg, Koue Bokkeveld, Groot Winterhoek, Hex River and Keeroms Mountains. Small portions of this shale band unit are found at Piketberg and Breëvlei north of Het Kruis. Altitude 400–1 650 m, with extremes from 100 m to lower altitude limits of FFs 30 Western Altimontane Sandstone Fynbos. See also Figure 4.78 featuring the simplified distribution of this unit.

Vegetation & Landscape Features A narrow 80–200 m linear feature, smooth and flat in profile compared to surrounding areas and thus favoured for paths and roads. The dominant landscape of the Cederberg (the long, linear plateaus) is often associated with the shale bands. At present the vegetation of this unit encompasses diverse shrublands ranging from karoo at lower altitudes and northerly aspects, renosterveld at low and medium altitudes on various aspects, to fynbos at higher altitudes and also much lower on southern aspects. Fynbos includes all structural types; it is often quite grassy in character, and usually waboomveld occurs at the lowest altitudes. Heuweltjies prominent in northern portion of the band.

Geology & Soils Clays derived from shales of the Cedarberg Formation. Land types mainly Ic and Ib.

Climate MAP 250–1 360 mm (mean: 590 mm), peaking from May to August. Mean daily maximum and minimum temperatures 27.2°C and 3.4°C for February and July, respectively. Frost incidence 10–30 days per year. See also climate diagram for FFb 1 Northern Inland Shale Band Vegetation (Figure 4.77).

Important Taxa ([A]Altimontane shale bands) Small Tree: *Protea nitida*. Tall Shrubs: *Metalasia densa* (d), *Dodonaea viscosa* var. *angustifolia*, *Leucadendron pubescens*, *L. rubrum*, *Liparia umbellifera*[A], *Protea laurifolia*, *P. punctata*. Low Shrubs: *Aspalathus triquetra* (d), *Elytropappus adpressus* (d), *E. rhinocerotis* (d), *Helichrysum dasyanthum* (d), *Leucadendron glaberrimum* subsp. *glaberrimum* (d), *Protea acuminata* (d), *Agathosma capensis*, *Anthospermum aethiopicum*, *Aspalathus grandiflora*, *A. juniperina* subsp. *monticola*[A], *A. lanifera*, *Athanasia cuneifolia*, *A. microphylla*, *Cliffortia baccans*, *C. ruscifolia*, *Cyclopia montana* var. *glabra*[A], *Gnidia geminiflora*, *Helichrysum cylindriflorum*, *Lachnaea elsieae*, *L. pedicellata*, *Leucadendron salignum*, *Lobostemon trichotomus*, *Microdon dubius*, *M.*

parviflorus, *Muraltia rhamnoides*, *Phylica leipoldtii*, *Polyarrhena imbricata*, *Protea scolopendriifolia*, *P. witzenbergiana*, *Serruria confragosa*. Succulent Shrub: *Ruschia lineolata*. Herbs: *Cotula andreae*[A], *Gazania serrata*. Geophytic Herbs: *Geissorhiza longifolia*, *Oxalis obtusa*, *O. stokoei*[A]. Graminoids: *Calopsis viminea* (d), *Cannomois parviflora* (d), *Ischyrolepis pygmaea*[A] (d), *I. unispicata* (d), *I. virgea* (d), *Pentaschistis eriostoma*[A] (d), *Willdenowia arescens* (d), *W. incurvata* (d), *Cannomois virgata*, *Ehrharta calycina*, *Elegia ebracteata*, *Ficinia deusta*, *Hypodiscus aboaristatus*, *H. neesii*, *Ischyrolepis capensis*, *I. laniger*, *I. sieberi*, *Merxmuellera rufa*, *M. stricta*, *Pentameris macrocalycina*, *Pentaschistis alticola*[A], *P. pallida*[A], *P. rosea* subsp. *purpurascens*[A], *Restio filiformis*, *Staberoha vaginata*[A], *Tetraria cuspidata*, *Tribolium hispidum*, *Willdenowia stokoei*.

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Figure 4.80 FFb 1 Northern Inland Shale Band Vegetation: Smooth shale slopes of the Cederberg Formation on the southern slopes of Conical Peak opposite the Matroosberg Peak of the Hex River Mountains (Western Cape). The vegetation is a high-altitude (1 900 m) restioid fynbos dominated by *Ischyrolepis pygmaeus* and with prominent asteraceous (*Helichrysum*, *Metalasia*) and spine-leaved (*Cliffortia*) shrubby components.

Endemic Taxa ([A]Altimontane shale bands) Low Shrubs: *Agathosma bodkinii*, *Aspalathus keeromsbergensis*, *A. orbiculata*, *A. shawii* subsp. *longispica*, *Athanasia bremeri*, *Metalasia phillipsii* subsp. *phillipsii*[A]. Herbs: *Bolandia argillacea*[A], *Lamprocephalus montanus*[A], *Roodebergia kitamurana*[A], *Wimmerella mariae*[A]. Geophytic Herb: *Geissorhiza erubescens*. Graminoids: *Cannomois aristata*, *Pentaschistis caulescens*.

Conservation Least threatened. Target 29%. More than 80% statutorily conserved in the Cederberg and Grootwinterhoek Wilderness Areas, Ceres Mountain Fynbos, Bokkeriviere and Ben Etive Nature Reserves as well as in mountain catchment areas such as Sederberg, Koue Bokkeveld, Matroosberg and Winterhoek. Only 4% transformed (cultivation). The only alien woody species of concern is *Pinus radiata*. Erosion very low.

Remarks The classification of the low-altitude (below altitude of 1 000 m) patches of this shale band unit, especially those in the central and southern Cederberg (so-called Pakhuis shale band of Taylor 1996), those of the Olifants River Valley south of Citrusdal as well as those embedded within FFs 6 Piketberg Sandstone Fynbos and FFs 2 Graafwater Sandstone Fynbos, is only tentative. According to available data, a small portion of these low-altitude shale bands at Pakhuis (see Community 8 in Taylor 1996) has a dry form of renosterveld (FRs 4 Ceres Shale Renosterveld), but the geographical limits of this type have not been mapped. At lower altitudes in the Olifants River Valley those portions of the shale band with SKk 7 Citrusdal Vygieveld have been mapped as such.

References Linder (1976), Nordenstam (1976), Taylor (1996).

FFb 2 Western Coastal Shale Band Vegetation

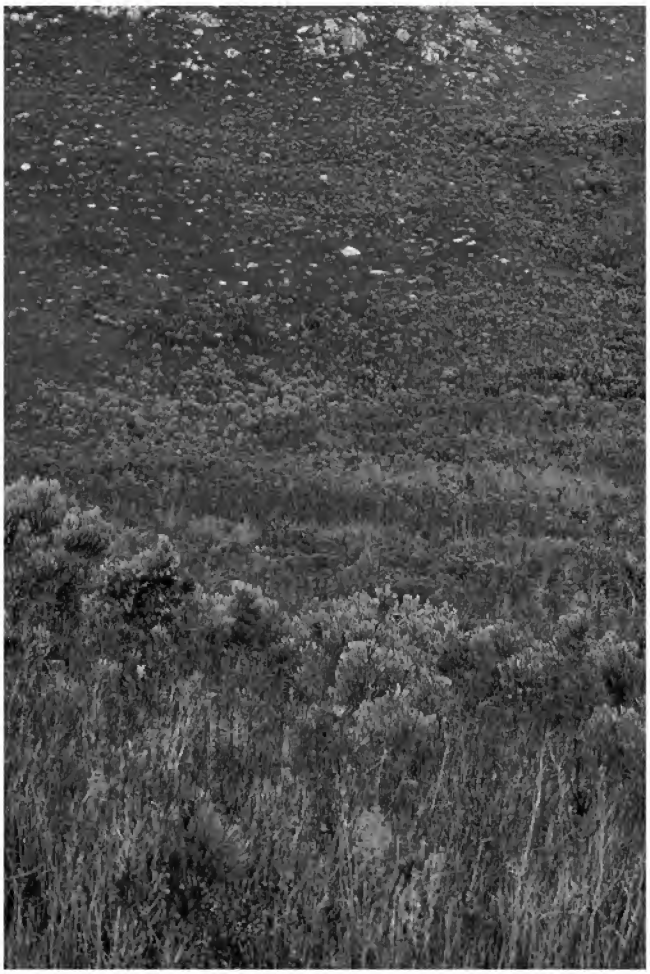
VT 69 Macchia (Fynbos) (90%) (Acocks 1953). Mesic Mountain Fynbos (94%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (96%) (Low & Rebelo 1996). BHU 53 Hawequas Mountain Fynbos Complex (34%), BHU 59 Riviersonderend Mountain Fynbos Complex (17%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

D. Gwynne-Evans

Figure 4.79 FFb 1 Northern Inland Shale Band Vegetation: Proteoid fynbos with *Leucadendron nitidum* on the Cedarberg Formation shale band with sandstone boulders on the Skurweberg northeast of Ceres (Western Cape).

Distribution Western Cape Province: Embedded within the mountain ranges of Elandskloof, Limietberge, Wellington Sneeukop, Slanghoek, Du Toitsberge, Klein Drakenstein, Wemmershoek, Stettyns, Franschhoek (including Victoria Peak and Emerald Dome), Groenland, Hottentots Holland (including Triplets and Somerset Sneeukop), and Kogelberg. These bands extend eastwards through the Kleinrivierberge, Caledon Swartberg and Bredasdorpberge. Also included are the shale bands of the Riviersonderend Mountains and of Potberg. Altitude 50–1 800 m. See also Figure 4.78 featuring the simplified distribution of this unit.

Vegetation & Landscape Features A narrow 80–200 m linear feature (up to 1 km wide in a few places and also forming rings on some 'Sneeukop' peaks),



A.G. Rebelo

Figure 4.81 FFb 2 Western Coastal Shale Band Vegetation: Proteoid fynbos dominated by *Leucadendron xanthoconus* with *Erica pillansii* with restioid fynbos dominated by *Elegia mucronata* on seeps on the Cedarberg Formation shale band above Kleinmond, Kogelberg (Western Cape).

smooth and flat in profile compared to surrounding areas. The band supports diverse renosterveld and fynbos shrublands of all structural types including waboomveld at lower altitudes.

Geology & Soils Clays derived from shale of the Cedarberg Formation. Land types mainly Ic and Ib.

Climate MAP 280–2 000 mm (mean: 1 070 mm), peaking from May to August. Southeasterly cloud brings heavy mist precipitation at higher altitudes in summer. Mean daily maximum and minimum temperatures 24.3°C and 5.0°C for February and July, respectively. Frost incidence 2–10 days per year. See also climate diagram for FFb 2 Western Coastal Shale Band Vegetation (Figure 4.77).

Important Taxa ([T]Cape thickets, [W]Wetlands) Small Trees: *Protea nitida* (d), *Widdringtonia nodiflora*. Tall Shrubs: *Leucadendron salicifolium* (d), *Montinia caryophyllacea* (d), *Protea neriifolia* (d), *Curtisia dentata*[T], *Diospyros glabra*[T], *Maytenus acuminata*[T], *Protea eximia*, *P. lepidocarpodendron*, *P. mundii*, *P. repens*, *Rapanea melanophloeos*[T]. Low Shrubs: *Anthospermum aethiopicum* (d), *Aulax umbellata* (d), *Berzelia lanuginosa*[W] (d), *Diastella divaricata* subsp. *montana* (d), *Elytropappus glandulosus* (d), *Erica equisetifolia* (d), *E. hispidula* (d), *E. quadrangularis* (d), *Leucadendron xanthoconus* (d), *Protea scabra* (d), *Agathosma capensis*, *Anthospermum galioides* subsp. *galioides*, *A. prostratum*, *Brunia neglecta*, *B. nodiflora*, *Cliffortia atrata*, *C. eriocephalina*, *C. polygonifolia*, *Clutia polygonoides*, *Diosma hirsuta*, *Erica filiformis*, *E. plukenetii* subsp. *plukenetii*, *E. viscaria* subsp. *longifolia*, *Euryops pinnatipartitus*, *Helichrysum tomentosulum*, *Leucadendron salignum*, *L. spissifolium* subsp. *spissifolium*, *Leucospermum cordifolium*, *Lonchostoma purpureum*, *Paranomus adiantifolius*, *Phylica spicata*, *Polyarrhena reflexa* subsp. *reflexa*, *Protea acaulos*, *P. cordata*, *P. longifolia*, *Rhus rosmarinifolia*[T], *Stoebe plumosa*. Herbs: *Peucedanum ferulaceum*, *P. strictum*. Geophytic Herbs: *Aristea racemosa* (d), *A. capitata*, *Blechnum capense*, *Elaphoglossum angustatum*, *Rumohra adiantiformis*. Graminoids: *Askidiosperma nitidum* (d), *Elegia filacea* (d), *E. hookeriana* (d), *E. mucronata* (d), *Ischyrolepis gaudichaudiana* (d), *I. monanthos* (d), *Pentaschistis colorata* (d), *Tetraria bromoides* (d), *T. cuspidata* (d), *Themeda triandra* (d), *Elegia juncea*, *E. stipularis*, *Epischoenus quadrangularis*, *Hypodiscus albo-aristatus*, *Ischyrolepis sieberi*, *Platycaulos cascadensis*[W], *Restio stokoei*, *Tetraria fimbriolata*.

Endemic Taxa Tall Shrub: *Protea lacticolor* (d). Low Shrubs: *Prismatocarpus cliffortioides*, *Protea caespitosa*. Succulent Shrub: *Lampranthus walgateae*. Geophytic Herbs: *Bobartia lilacina*, *Moraea lilacina*. Graminoid: *Pentameris hirtiglumis*.

Conservation Least threatened. The target of 30% has been achieved since almost 45% of the unit is protected in statutory and local authority reserves such as Limietberg, Kogelberg, Riviersonderend, Hottentots Holland, Theewaters, De Hoop and Waterval, while an additional almost 30% is protected in mountain catchment areas such as Hawequas, Riviersonderend and Hottentots Holland. Small patches are protected in a number of private reserves. Some 6% transformed by pine plantations. Aliens *Pinus pinaster* and *Hakea sericea* scattered on about half of the area of the unit. Erosion generally very low.

Remark 1 Although classified within this shale band unit, the shale band of Potberg has several prominent species (e.g. *Protea aurea*, *P. coronata*) shared with the FFb 3 Central Inland Shale Band Vegetation. Further vegetation studies are needed to clarify these links.

Remark 2 These shale bands often support small patches of afrotemperate forest in gullies and on saddles.

References Boucher (1972, 1977, 1978), Kruger (1974, 1979), Anonymous (1979), Van Wilgen & Kruger (1985), Sieben (2003).

FFb 3 Central Inland Shale Band Vegetation

VT 70 False Macchia (93%) (Acocks 1953). Mesic Mountain Fynbos (58%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (94%) (Low & Rebelo 1996). BHU 68 Groot Swartberg Mountain Fynbos Complex (35%), BHU 67 Rooiberg Mountain Fynbos Complex (23%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Shale bands of the Klein and Groot Swartberge, Touwsberg, Sandberg, Rooiberg, Gamkaberg and Kammanassie. Altitude 500–1 800 m. See also Figure 4.78 featuring the simplified distribution of this unit.

Vegetation & Landscape Features A narrow 80–200 m (wider in places), linear, smooth and flat feature of high-altitude slopes or mountain ridges. Vegetation diverse, from karoo shrublands at lower altitudes, to renosterveld and fynbos shrublands. Fynbos includes all structural types including graminoid fynbos, and usually waboomveld and asteraceous fynbos at lowest altitudes.

Geology & Soils Clays derived from shale of the Cedarberg Formation. Land types mainly Ic and Ib.

Climate MAP 140–980 mm (mean: 460 mm), relatively even with a bimodal peak in March and November and a low in

December–January. Mean daily maximum and minimum temperatures 28.2°C and 1.7°C for January and July, respectively. Frost incidence 10–40 days per year. See also climate diagram for FFb 3 Central Inland Shale Band Vegetation (Figure 4.77).

L. Mucina

Figure 4.82 FFb 4 Central Coastal Shale Band Vegetation: Wet proteoid fynbos on the Cedarberg Formation shale band (continuing up the valley in the background) on Garcia Pass, Langeberg (Western Cape).

Important Taxa ([A]Altimontane shale bands) Small Tree: *Protea nitida*. Tall Shrubs: *Cliffortia burchellii*, *Leucadendron rubrum*, *Protea eximia*, *P. punctata*, *P. repens*. Low Shrubs: *Anthospermum galioides* subsp. *galioides*, *Aspalathus juniperina* subsp. *monticola*, *Cliffortia tuberculata*, *Leucadendron album*, *L. salignum*, *L. spissifolium* subsp. *fragrans*, *Leucospermum wittebergense*, *Metalasia pallida*, *M. rhoderoides*, *Protea lorifolia*, *Stoebe plumosa*. Herbs: *Corymbium glabrum*, *Cotula andreae*[A]. Geophytic Herb: *Aristea pusilla* subsp. *pusilla*. Graminoids: *Willdenowia teres* (d), *Hypodiscus aristatus*, *H. synchroolepis*, *Ischyrolepis nana*, *Merxmuellera stricta*, *Tetraria ustulata*.

Endemic Taxa ([A]Altimontane shale bands) Low Shrub: *Acmadenia baileyensis*. Succulent Shrub: *Lampranthus swartbergensis*[A].

Conservation Least threatened. The target of 27% has been achieved since 68% of the unit already protected in statutory reserves such as Groot Swartberg, Kammanassie, Towerkop, Swartberg East, Gamkaberg and Rooiberg. Additionally almost 25% is protected in mountain catchment areas such as Kammanassie, Klein Swartberg, Rooiberg, Swartberg-oos and Groot Swartberg. Only about 1% transformed so far. Woody aliens include *Pinus pinaster*, *P. radiata*, *P. halepensis* and *Hakea sericea*. Erosion very low and low.

Reference Bond (1981).

FFb 4 Central Coastal Shale Band Vegetation

VT 70 False Macchia (57%) (Acocks 1953). Mesic Mountain Fynbos (76%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (82%) (Low & Rebelo 1996). BHU 64 Southern Langeberg Mountain Fynbos Complex (52%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: A virtually continuous band traversing the entire length of the Langeberg, with bands in the eastern regions of the Outeniqua Mountains and of the Grootberg-Amandelbosberg as well as some areas, for example Die Bergies, west of Mossel Bay. The extent of the shale band in the Outeniqua Mountains has not been adequately mapped and its eastern boundary remains unknown. Altitude 50–1 700 m. See also Figure 4.78 featuring the simplified distribution of this unit.

Vegetation & Landscape Features A narrow 80–200 m linear feature (wider in places), smooth and flat in profile compared to surrounding areas. Vegetation comprises various fynbos shrublands.

Geology & Soils Clays derived from shale band of the Cedarberg Formation. Land types mainly Ib, Ic and Db.

Climate MAP 280–1 560 mm (mean: 680 mm), relatively even with a low in December–January. Southeasterly cloud brings heavy mist precipitation at higher altitudes in summer. Mean daily maximum and minimum temperatures 27.2°C and 4.8°C for January and July, respectively. Frost incidence 3–10 days per year. See also climate diagram for FFb 4 Central Coastal Shale Band Vegetation (Figure 4.77).

Important Taxa Tall Shrubs: *Leucadendron eucalyptifolium* (d), *Protea aurea* subsp. *aurea* (d), *P. neriifolia* (d), *P. coronata*, *P. eximia*. Low Shrubs: *Erica hispidula* (d), *Phylica pinea* (d), *P. rubra* (d), *Aspalathus juniperina* subsp. *monticola*, *Aulax cancellata*, *Cliffortia atrata*, *Cyclopia sessiliflora*, *Erica pubigera*, *Helichrysum pandurifolium*, *Hermannia stricta*, *Indigofera sarmentosa*, *Leucadendron salignum*, *Mimetes cucullatus*, *Pelargonium cordifolium*, *Protea cynaroides*, *P. grandiceps*, *Senecio lineatus, Serruria fasciflora*, *Stoebe plumosa*. Herbs: *Alepidea capensis*, *Carpacoce spermacocea*, *Knowltonia capensis*. Geophytic Herbs: *Lanaria lanata* (d), *Geissorhiza hesperanthoides*, *G. nubigena*. Graminoids: *Cannomois virgata* (d), *Ischyrolepis hystrix* (d), *Tetraria bromoides* (d), *T. flexuosa* (d), *Ehrharta dura*, *Pentaschistis malouinensis*.

Conservation Least threatened. Target 27%. About 25% conserved in statutory and local-authority reserves such as Boosmansbos Wilderness Area, Marloth, Garcia, Tygerberg, Montagu Mountain, Ruitersbos, Twistniet and Spioenkop. In addition 43% enjoys protection in mountain catchment areas such as Langeberg-wes, Langeberg-oos and Matroosberg. Some 15% transformed (mainly cultivation, but also pine plantations). Aliens such as *Pinus pinaster*, *Hakea sericea* and *Acacia mearnsii* are locally of concern. Erosion very low and low.

References Boucher (1972, 1977, 1978, 1988a), McDonald (1993a, b, c, 1995).

FFb 5 Eastern Inland Shale Band Vegetation

VT 70 False Macchia (94%) (Acocks 1953). Mesic Grassy Fynbos (55%) (Moll & Bossi 1983). LR 65 Grassy Fynbos (55%) (Low & Rebelo 1996). BHU 73 Baviaanskloof Mountain Fynbos Complex (40%), BHU 72 Kouga Mountain Fynbos Complex (31%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Eastern and Western Cape Provinces: Shale bands of the Kougaberge and Baviaanskloofberge with parallel occurrences to the south but remaining north of the Langkloof. Also on Antoniesberg, south of Willowmore. Altitude 250–1 650 m. See also Figure 4.78 featuring the simplified distribution of this unit.

Vegetation & Landscape Features A narrow 80–200 m (greater widths in the uppermost Baviaanskloof area), linear, smooth and flat landscape feature supporting various shrublands, from thicket, renosterveld and fynbos at higher altitudes. Fynbos includes all structural types, but predominantly graminoid fynbos.

Geology & Soils Clays derived from shale of the Cedarberg Formation. Land types mainly Ib, Fa, Fb and Ic.

Climate MAP 290–910 mm (mean: 535 mm), relatively even with a slight peak in March. Mean daily maximum and minimum temperatures 26.9°C and 3.3°C for February and July, respectively. Frost incidence 2–40 days per year. See also climate diagram for FFb 5 Eastern Inland Shale Band Vegetation (Figure 4.77).

Important Taxa Small Tree: *Protea nitida*. Tall Shrubs: *Protea neriifolia* (d), *P. repens* (d), *Leucadendron eucalyptifolium*, *Protea punctata*. Low Shrubs: *Elytropappus rhinocerotis*, *Lachnaea glomerata*, *Leucadendron salignum*, *Leucospermum cuneiforme*, *Protea intonsa*, *P. tenax*. Herb: *Hebenstretia integrifolia*. Graminoid: *Themeda triandra*.

Endemic Taxon Low Shrub: *Aspalathus incana*.

Conservation Least threatened. Target 27%. Statutorily conserved (38%) in the Kouga, Guerna and Berg Plaatz Wilderness Areas. Small patches also protected in private nature reserves (Sustersdal). Some 7% transformed (cultivation). Alien *Pinus pinaster* occurs in places. Erosion is low and very low.

FFb 6 Eastern Coastal Shale Band Vegetation

VT 70 False Macchia (54%) (Acocks 1953). Mesic Grassy Fynbos (30%), Wet Mountain Fynbos (12%), Mesic Mountain Fynbos (7%), Afro-Montane Forest (4%) (Moll & Bossi 1983). LR 65 Grassy Fynbos (46%), LR 2 Afromontane Forest (34%) (Low & Rebelo 1996). BHU 100 Knysna Afromontane Forest (34%), BHU 29 Langkloof Fynbos/Renosterveld Mosaic (22%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western and Eastern Cape Provinces: Shale bands in the eastern Outeniqua (often also bearing forest patches), Langkloof, Tsitsikamma and Kareedouw Mountains and along the southern Cape coastal plains to around Oyster Bay with the most seaward belt reaching the coast at, for example, Clinton's Bank south of Bloukrans Pass. Altitude 0–1 100 m. See also Figure 4.78 featuring the simplified distribution of this unit.

Vegetation & Landscape Features Shale bands form narrow 80–200 m, linear, smooth and flat landscape features and support various shrublands, ranging from thicket to renosterveld and fynbos at higher altitudes. Fynbos includes all structural types, quite often grassy in character.

Geology & Soils Clays derived from shale of the Cedarberg Formation. Land types mainly Db, Ca, Bb, and Ib.

Climate MAP 500–1 140 mm (mean: 815 mm), relatively even with a bimodal peak in March and August–November. Mean daily maximum and minimum temperatures 25.1°C and 7.0°C for January–February and July, respectively. Frost incidence 0–20 days per year. See also climate diagram for FFb 6 Eastern Coastal Shale Band Vegetation (Figure 4.77).

Important Taxa Tall Shrubs: *Leucadendron eucalyptifolium*, *Protea neriifolia*. Low Shrubs: *Leucadendron salignum*, *Leucospermum cuneiforme*.

Conservation Endangered. Target 27%. Statutorily conserved (16%) in the proposed Garden Route National Park (including Tsitsikamma National Park), Koomans Bush State Reserve as well as in Lottering Forest Reserve, Plaatbos Nature Reserve, Kwaaibrand and Langebosch Forest Reserves and several other private conservation areas. Some 65% transformed, with cultivation accounting for most of the transformation, followed by pine plantations. Alien *Pinus pinaster* and *Hakea sericea* occur as scattered. Erosion is very low.

Remark Large portions of the shale band in this area support FOz 6 Southern Coastal Forest and these areas are mapped as such.

Reference Bond (1981).

9.1.6 Silcrete, Ferricrete and Conglomerate Fynbos

Silcrete, ferricrete and conglomerate fynbos types are intermediate between shale and sandstone fynbos in character. Like shale fynbos, their ecology is poorly known, but probably approximates shale fynbos rather than sandstone fynbos in most features. They thus fit in the zone between renosterveld and fynbos and are dominated by mesotrophic asteraceous and proteoid fynbos types.

The designation of units within this category is largely arbitrary, and does not necessarily apply to the most abundant or characteristic unit. Few are in fact a single geology—most include silcrete, laterite, conglomerate and some igneous rocks. Together these units comprise less than 5% the area of fynbos.

FFc 1 Swellendam Silcrete Fynbos

VT 46 Coastal Renosterbosveld (59%) (Acocks 1953). South Coast Renosterveld (62%) (Moll & Bossi 1983). LR 63 South and South-west Coast Renosterveld (85%) (Low & Rebelo 1996). BHU 19 Suurbraak Grassy Fynbos (41%), BHU 34 Riversdale Coast Renosterveld (29%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Relatively large patches on southern foothills of the Langeberg from around Swellendam to north of Dekriet/Soutpan (between Riversdale and Albertinia), becoming highly fragmented between Albertinia and the southern side of Robinson Pass to around Molenrivier (north of Klein-Brak River). Altitude 100–400 m.

Vegetation & Landscape Features Mainly undulating hills on the coastal forelands, the remains of the old African surface. Structurally it is a medium tall evergreen shrubland or grassland. Predominantly asteraceous fynbos, but graminoid fynbos on summits and northern slopes where disturbed. Proteoid fynbos occurs on southern slopes and ericaceous fynbos is found in wetter habitats. Afrotemperate forest occurs in fire-safe alluvial areas, such as along perennial rivers. It is uncertain whether proteoid fynbos, renosterveld or thicket was the dominant type in some of the eastern plateaus—it has all been converted to pasture.

Geology & Soils Silcrete and conglomerate with dry, shallow, loamy sand of Houwhoek form. Land types mainly Db and Gb.

Climate MAP 320–860 mm (mean: 520 mm), with no clear peak, but a low in December–January. Mean daily maximum and minimum temperatures 28°C and 5.5°C for January and July, respectively. Frost incidence about 3 days per year. See also climate diagram for FFc 1 Swellendam Silcrete Fynbos (Figure 4.83).

Important Taxa Tall Shrubs: *Erica prolata* (d), *Leucadendron eucalyptifolium*, *Metalasia densa*, *Passerina corymbosa*, *Protea*

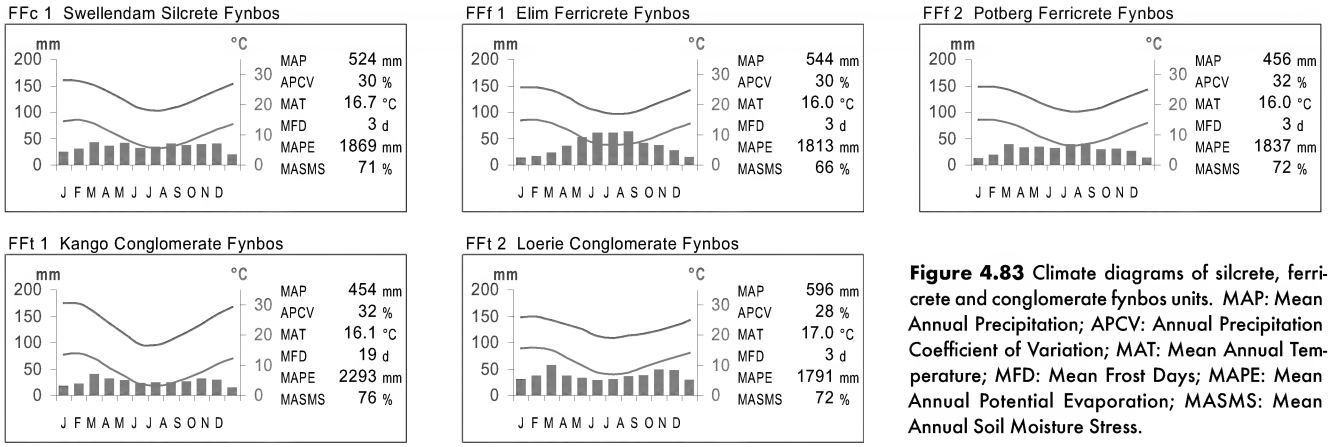


Figure 4.83 Climate diagrams of silcrete, ferricrete and conglomerate fynbos units. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days; MAPE: Mean Annual Potential Evaporation; MASMS: Mean Annual Soil Moisture Stress.

coronata, *P. neriifolia*, *P. repens*. Low Shrubs: *Cliffortia ruscifolia* (d), *Leucadendron salignum* (d), *Agathosma foetidissima*, *Elytropappus rhinocerotis*, *Erica klotzschii*, *E. peltata*, *Euchaetis longicornis*, *Leucadendron brunioides* var. *brunioides*, *L. teretifolium*, *Leucospermum calligerum*, *L. cuneiforme*, *Morella quercifolia*, *Oedera imbricata*, *Pelargonium ovale*, *Protea decurrens*, *Salvia chamelaeagnea*, *Serruria acrocarpa*, *Stoebe plumosa*. Herbs: *Berkheya armata*, *Helichrysum crispum*. Geophytic Herbs: *Bobartia macrospatha* subsp. *macrospatha*, *Lanaria lanata*. Herbaceous Climber: *Cyphia volubilis*. Graminoids: *Cymbopogon marginatus*, *Cynodon dactylon*, *C. incompletus*, *Ehrharta ramosa* subsp. *aphylla*, *Eragrostis capensis*, *Ischyrolepis triflora*, *Juncus scabriusculus*, *Merxmuellera stricta*, *Pentaschistis eriostoma*, *Restio triticeus*, *Themeda triandra*.

Endemic Taxa Tall Shrub: *Psoralea filifolia*. Low Shrubs: *Acmadenia laxa*, *Chrysocoma flava*, *Erica burchelliana*, *E. filamentosa*, *E. physantha*, *Gnidia strigillosa*, *Wahlenbergia effusa*. Succulent Shrub: *Ruschia cymbifolia*. Geophytic Herbs: *Cyrtanthus leptosiphon*, *Geissorhiza foliosa*, *Gladiolus bilineatus*, *G. engysiphon*. Graminoid: *Isolepis brevicaulis*.

Conservation Endangered. Target 30%. Only 4% statutorily conserved in the Bontebok National Park and small patches also in Langeberg-oos (mountain catchment area). More than 40% already transformed for cultivation (pastures) and pine plantations. Alien *Acacia cyclops* occurs in places. Erosion generally moderate and very low, but also high in some places.

Remarks This little known vegetation unit shows floristic features of both fynbos and of renosterveld. Overgrazing converts this to graminoid fynbos on the northern slopes and to a species-poor renosterveld elsewhere. It appears to be easily converted to pasture by frequent burning and liming.

References Grobler & Marais (1967), Taylor (1972a), Rebelo et al. (1991), McDonald (1993b), C. Boucher (unpublished data), L. Mucina (unpublished data).

FFf 1 Elim Ferricrete Fynbos

VT 47 Coastal Macchia (65%) (Acocks 1953). Mesic Mountain Fynbos (22%), Elim Fynbos (20%) (Moll & Bossi 1983). LR 66 Laterite Fynbos (55%) (Low & Rebelo 1996). BHU 27 Elim Fynbos/Renosterveld Mosaic (60%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Extensive areas between the Bot River Valley, Hemel en Aarde Valley, Stanford environs, Salmonsdam and Baardskeerdersbos, with the most extensive parts around Elim on the Agulhas Plain spanning the area from Soetmuisberg in the north to Buffeljags and the Soetanysberg in the south. Outliers found on the northern slopes of the mountains adjacent to those of the Rûens around Napier and at Perdekamp north of Arniston. Altitude 20–300 m.

L. Mucina

Figure 4.84 FFc 1 Swellendam Silcrete Fynbos: Regenerating one-year old proteoid fynbos with resprouting *Leucadendron salignum* on gravel terraces, regularly burned for grazing, in the Bontebok National Park near Swellendam (Western Cape).

Vegetation & Landscape Features Undulating hills and plains covered with open to closed dwarf shrubland with occasional scattered tall shrubs. It is a diverse unit, with all structural fynbos types present, but with extensive areas of asteraceous fynbos dominated by low proteoid elements. To differentiate mesotrophic asteraceous from mesotrophic proteoid fynbos the following proteoid types are recognised: *Leucadendron elimense*, *L. laxum*, *L. modestum*, *L. stelligerum* and *L. teretifolium*. When degraded, this vegetation type becomes dominated by *Elytropappus rhinocerotis*. On transitions to deep sandy soils, *Protea repens* may be dominant, and these transitional communities are often much richer in species than associated FFs 12 Overberg Sandstone Fynbos.

L. Mucina

Figure 4.85 FFf 1 Elim Ferricrete Fynbos: Remnant patch of proteoid fynbos dominated by *Leucadendron salignum* and *L. elimense* subsp. *elimense*, with *Acacia*-invaded river course in the background, near Viljoenshof on the Agulhas Plain (Western Cape).

Geology & Soils Glenrosa and Mispah and prismacutanic and pedocutanic soils, derived from Bokkeveld Shale, Cape Granite (of the Hermanus Suite), and ferricrete and silcrete. Land types mainly Fb and Db.

Climate Mainly winter-rainfall regime, also with some summer rain. MAP 350–770 mm (mean: 545 mm), peaking from May to August. Mean daily maximum and minimum temperatures 25.8°C and 6.7°C for January and July, respectively. Frost incidence about 3 days per year. See also climate diagram for FFf 1 Elim Ferricrete Fynbos (Figure 4.83).

Important Taxa Tall Shrub: *Protea repens* (d). Low Shrubs: *Elytropappus rhinocerotis* (d), *Erica klotzschii* (d), *E. puberuliflora* (d), *Leucadendron modestum* (d), *Metalasia acuta* (d), *Stoebe capitata* (d), *Aspalathus pycnantha*, *Aulax umbellata*, *Cliffortia ruscifolia*, *Cymbopappus adenosolen*, *Disparago anomala*, *Erica brachysepala*, *E. bruniifolia*, *E. lasciva*, *E. nudiflora*, *E. plukenetii* subsp. *bredensis*, *E. regia* subsp. *regia*, *Leucadendron linifolium*, *L. salignum*, *L. teretifolium*, *L. xanthoconus*, *Leucospermum pedunculatum*, *Mimetes cucullatus*, *Phylica ericoides*, *Protea aspera*, *P. longifolia*, *P. subulifolia*, *Serruria fasciflora*, *Xiphotheca guthriei*. Succulent Shrub: *Drosanthemum asperulum*. Herb: *Corymbium africanum*. Geophytic Herb: *Tritoniopsis flexuosa*. Graminoids: *Ficinia oligantha*, *F. tristachya*, *Ischyrolepis caespitosa*, *I. capensis*, *I. triflora*, *Karroochloa purpurea*, *Merxmuellera stricta*, *Pentaschistis colorata*, *P. eriostoma*, *Rhodocoma fruticosa*, *Tribolium brachystachyum*.

Endemic Taxa ([W]Wetlands) Low Shrubs: *Leucadendron laxum* (d), *L. stelligerum* (d), *Leucospermum heterophyllum* (d), *Agathosma joubertiana*, *A. minuta*, *A. virgata*, *Cliffortia phyllanthoides*, *Cliffortia* sp. nov. (*N. Helme 2088* BOL), *Erica brownii*, *E. flexistyla*[W], *E. jasminiflora*, *E. rubiginosa*, *E. ustulescens*, *Euchaetis diosmoides*, *Gnidia ornata*, *Leucadendron elimense* subsp. *elimense*, *L. elimense* subsp. *salteri*, *Muraltia cuspifolia*, *M. cyclolopha*, *M. hirsuta*, *Otholobium lanceolatum*, *Phylica diosmoides*, *P. incurvata*, *P. laevifolia*, *Protea pudens*, *Pteronia scabra*. Succulent Shrub: *Acrodon parvifolius*. Geophytic Herb: *Gladiolus acuminatus*. Graminoid: *Calopsis pulchra*.

Conservation Endangered. Target 30%. This vegetation type is known to be a major node of Red Data plant taxa. Statutorily conserved in the Agulhas National Park (5%) and small patches in the Oude Bosch Private Nature Reserve. Some 42% transformed (cultivation of wheat, pastures, vineyards). Alien *Acacia cyclops*, *A. saligna*, *Pinus pinaster*, *Hakea gibbosa*, *H. sericea*, species of *Eucalyptus* and *Leptospermum laevigatum* are common invaders. Erosion low and very low.

Remarks This unit is a major regional centre of endemism located on the Agulhas Plain, significant especially for the high number of endemic Proteaceae. Some regional endemic taxa are shared with FRc 2 Rûens Silcrete Renosterveld.

References Cowling et al. (1988), Thwaites & Cowling (1988), Mustart et al. (1997), N. Helme (unpublished data), J.A.M. Janssen (unpublished data).

FFf 2 Potberg Ferricrete Fynbos

VT 46 Coastal Renosterbosveld (72%) (Acocks 1953). Mesic Mountain Fynbos (13%) (Moll & Bossi 1983). LR 63 South and South-west Coast Renosterveld (79%) (Low & Rebelo 1996). BHU 34 Riversdale Coast Renosterveld (78%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Northern and western lowermost slopes of Potberg Mountain from Potberg to Poortsrivier and bordered on the north by the Breede River from Diepkloof eastwards. Altitude 20–220 m.

Vegetation & Landscape Features Slight slopes and moderately undulating plains perched on the northern slopes below Potberg. A medium tall evergreen shrubland. Asteraceous and

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Figure 4.86 FFf 2 Potberg Ferricrete Fynbos: Proteoid fynbos with *Leucadendron modestum* dominant on ferricrete plains in the Potberg section of De Hoop Nature Reserve in the Overberg (Western Cape).

proteoid fynbos are dominant, with localised stands of restioid fynbos.

Geology & Soils Ferricrete with dry, shallow loamy sand; also silcrete and Ordovician sandstone of the Table Mountain Group (Cape Supergroup) colluvium over shales. Shallow stony soils and sandy loams derived from shale. Rounded ferricrete stones, gravel and cobble covering the surface are locally called 'koffieklip' due to their brown colour. They are considered to be remains of the old African surface. Land types mainly Db, Fc, Fa and Fb.

Climate MAP 300–540 mm (mean: 455 mm), with no clear peak but a low from December to February. Mean daily maximum and minimum temperatures 26.0°C and 6.2°C for January–February and July, respectively. Frost incidence about 3 days per year. See also climate diagram for FFf 2 Potberg Ferricrete Fynbos (Figure 4.83).

Important Taxa Tall Shrubs: *Protea repens* (d), *P. neriifolia*, *Rhus pallens*. Low Shrubs: *Elytropappus rhinocerotis* (d), *Erica quadrangularis* (d), *Leucadendron modestum* (d), *Amphithalea ciliaris*, *Chrysanthemoides monilifera*, *Erica imbricata, E. puberuliflora, E. viscaria* subsp. *longifolia, Leucadendron coriaceum*, *L. cryptocephalum*, *L. salignum*, *L. teretifolium*, *Oedera squarrosa*, *Serruria ludwigii*. Graminoids: *Cymbopogon pospischilii*, *Ficinia oligantha*, *Ischyrolepis capensis*, *Karroochloa purpurea*, *Merxmuellera stricta*.

Endemic Taxon Geophytic Herb: *Bulbinella potbergensis*.

Conservation Endangered. Target 30%. According to current coverage, about 6% of the unit is statutorily conserved in De Hoop Nature Reserve. About 40% of the area transformed (cultivation). *Acacia cyclops* and *A. saligna* are notable invading aliens. Erosion moderate and very low.

Remark This little known vegetation unit has features of both fynbos and of renosterveld. *Elytropappus rhinocerotis* is present but not very conspicuous. It shares features with similar communities occurring on ferricrete or silcrete surfaces, and has the largest extant populations of Red Data silcrete endemics such as *Leucadendron coriaceum*, *L. cryptocephalum* and *Protea decurrens*.

FFt 1 Kango Conglomerate Fynbos

VT 25 Succulent Mountain Scrub (Spekboomveld) (38%), VT 43 Mountain Renosterbosveld (30%) (Acocks 1953). South Coast Renosterveld (72%) (Moll & Bossi 1983). LR 63 South and South-west Coast Renosterveld (74%) (Low & Rebelo 1996). BHU 43 Kango Inland Renosterveld (75%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Northern foothills of the Little Karoo basin, south of the Groot Swartberg, from Gamkapoort to Barandas. Usually at higher altitude than the adjacent FRl 1 Kango Limestone Renosterveld such as on the Andriesberg. Altitude 400–1 200 m.

Vegetation & Landscape Features High foothills, tending to have flat summits, but well dissected. Vegetation a dense shrubland, especially on southern aspects and higher slopes where it is represented by proteoid and asteraceous fynbos and some graminoid fynbos. Upper southern slopes very dense proteoid fynbos.

Geology & Soils Shallow to deep, often yellow-red apedal soils derived chiefly from Cango sandstones, but also Buffelskloof conglomerate and dolerite intrusions. Land types mainly Ib.

Climate MAP 230–730 mm (mean: 455 mm), relatively even, but with a peak in March and a low in December–January. Mean daily maximum and minimum temperatures 30.6°C and 3.1°C for January and July, respectively. Frost incidence 10–20 days per year. See also climate diagram for FFt 1 Kango Conglomerate Fynbos (Figure 4.83).

Important Taxa ([T]Cape thickets) Small Tree: *Protea nitida*. Tall Shrubs: *Dodonaea viscosa* var. *angustifolia* (d), *Leucadendron rubrum* (d), *Protea repens* (d), *Freylinia lanceolata*, *Rhus angustifolia*[T], *R. incisa*[T]. Low Shrubs: *Anthospermum aethiopicum* (d), *Elytropappus rhinocerotis* (d), *Muraltia ericaefolia* (d), *Paranomus dregei* (d), *Passerina obtusifolia* (d), *Agathosma recurvifolia*, *A. roodebergensis*, *Anisodontea scabrosa*, *Athanasia filiformis*, *A. trifurcata*, *Cliffortia ruscifolia*, *Hermannia holosericea*, *Leucadendron salignum*, *Leucospermum cuneiforme*, *L. wittebergense*, *Muraltia ericoides*, *Paranomus dispersus*, *Protea intonsa*, *P. lorifolia*, *Psoralea oligophylla*. Succulent Shrub: *Crassula nudicaulis*. Geophytic Herb: *Drimia intricata*. Graminoids: *Cannomois scirpoides*, *Carex glomerabilis*, *Cymbopogon marginatus*, *Ischyrolepis gaudichaudiana*, *Karroochloa curva*, *Thamnochortus fruticosus*.

Endemic Taxa Low Shrub: *Lessertia lanata*. Succulent Herbs: *Conophytum truncatum* subsp. *truncatum* var. *wiggettiae*, *Haworthia blackburniae* var. *derustensis*, *H. monticola* var. *asema*. Graminoid: *Rhodocoma arida*.

Conservation Least threatened. Target 27%. Conserved for instance in the Swartberg Nature Reserve, Swartbergoos (mountain catchment area) and Groot Swartberg. Only about 2% has been transformed (cultivation). This is largely an unploughable unit occurring on the summit of rugged hills. Erosion low and very low.

Remarks The ecology and floristics of this unit are largely unknown. The name 'conglomerate' is for expediency only as it occurs equally on sandstones and dolerites in this area. This unit grades into FRl 1 Kango Limestone Renosterveld in the south and at lower altitudes and shares with it the high abundances and dominance of *Dodonaea viscosa* var. *angustifolia*. On steep north-facing slopes, and especially in kloofs, spekboom thickets dominated by *Portulacaria afra* border on the vegetation of this 'conglomerate fynbos'. Narrow, fire-protected ravines on the southern slopes shelter remnants of afrotemperate forest.

References Moffett & Deacon (1977), Vlok & Euston-Brown (2002).

FFt 2 Loerie Conglomerate Fynbos

VT 70 False Macchia (59%) (Acocks 1953). Mesic Grassy Fynbos (29%), Valley Bushveld (28%) (Moll & Bossi 1983). LR 63 South and South-west Coast Renosterveld (34%), LR 65 Grassy Fynbos (28%) (Low & Rebelo 1996). BHU 30 Kromme Fynbos/Renosterveld Mosaic (41%), BHU 21 Humansdorp Grassy Fynbos (40%) (Cowling et al. 1999b, Cowling & Heijnis 2001). STEP Loerie Fynbos Thicket (31%), STEP Andrieskraal Fynbos Thicket (15%), STEP Zuurberg Forest Thicket (5%) (Vlok & Euston-Brown 2002).

Distribution Eastern Cape Province: Hankey Valley on both sides of the Gamtoos River, from Andrieskraal to Mondplaas on the southwestern side, and Patensie to Thornhill on the northeastern side. Also found in the lower Kwazunga Valley above Springfield and Rooikrans near Uitenhage. Altitude 80–400 m.

Vegetation & Landscape Features Moderately undulating plains dissected by major rivers. Vegetation low shrubland or grassland with sparse emergent tall shrubs, and rich in succulents and geophytes. Structurally these are graminoid, asteraceous and proteoid fynbos types.

Geology & Soils Acidic, moist clay-loam, Glenrosa and Mispah soils and conglomerates associated with shales and conglomer-

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Figure 4.87 FFt 2 Loerie Conglomerate Fynbos: Mixed *proteaceous-ericaceous* fynbos with *Leucadendron salignum* and *Erica* species near Hankey (Eastern Cape).

ates of the Karoo Uitenhage sequence. Land types mainly Fc, Fa and Ib.

Climate MAP 360–780 mm (mean: 600 mm), even throughout the year with a slight bimodal peak in March and October–November. Mean daily maximum and minimum temperatures 26.1°C and 6.9°C for February and July, respectively. Frost incidence about 3 days per year. See also climate diagram for FFt 2 Loerie Conglomerate Fynbos (Figure 4.83).

Important Taxa ([T]Cape thickets) Tall Shrubs: *Aspalathus nivea*, *Azima tetracantha*[T], *Cliffortia linearifolia*, *Diospyros pallens*[T], *Dodonaea viscosa* var. *angustifolia*, *Euclea undulata*[T], *Grewia occidentalis*[T], *Gymnosporia capitata*[T], *Protea neriifolia*, *P. repens*, *Schotia afra* var. *afra*[T]. Low Shrubs: *Anthospermum galioides* subsp. *galioides*, *Asparagus subulatus*, *Barleria pungens*, *Cliffortia ruscifolia*, *Clutia polifolia*, *Elytropappus rhinocerotis*, *Erica demissa*, *E. pectinifolia*, *Felicia muricata* subsp. *cinerascens*, *Galenia secunda*, *Helichrysum anomalum*, *H. odoratissimum*, *H. zeyheri*, *Indigofera denudata*, *Leucadendron salignum*, *Leucospermum cuneiforme*, *Otholobium pictum*, *Passerina obtusifolia*, *Pelargonium odoratissimum*, *Protea foliosa*, *Senecio linifolius*. Succulent Shrubs: *Cotyledon orbiculata* var. *oblonga*, *Crassula cultrata*, *C. tetragona*, *Euphorbia polygona*. Woody Climbers: *Capparis sepiaria* var. *citrifolia*, *Rhoicissus digitata*. Woody Succulent Climber: *Zygophyllum foetidum*. Small Tree: *Protea nitida*. Herbs: *Commelina africana*, *Hibiscus pusillus*, *Salvia triangularis*. Geophytic Herbs: *Babiana patersoniae*, *Drimia intricata*, *Geissorhiza bracteata*, *Gladiolus longicollis*, *Polyxena ensifolia*, *Sansevieria hyacinthoides*, *Spiloxene trifurcillata*. Succulent Herbs: *Crassula nemorosa*, *Haworthia cooperi*. Herbaceous Climber: *Cyphia sylvatica*. Herbaceous Succulent Climbers: *Ceropegia cancellata*, *Pelargonium peltatum*. Graminoids: *Aristida junciformis* subsp. *galpinii*, *Brachiaria serrata*, *Cymbopogon marginatus*, *Cynodon dactylon*, *Eragrostis obtusa*, *Eustachys paspaloides*, *Ficinia tristachya*, *Ischyrolepis gaudichaudiana*, *I. sieberi*, *Pentaschistis angustifolia*, *P. colorata*, *Restio triticeus*, *Sporobolus africanus*, *Stipa dregeana*, *Tetraria cuspidata*, *Themeda triandra*, *Trachypogon spicatus*.

Endemic Taxon Succulent Shrub: *Erepsia aristata*.

Conservation Least threatened. Target 23%. Some 11% statutorily conserved in the Groendal Wilderness Area. Small patches are also found in the private Kabeljous River Natural Heritage Site. About 9% transformed (cultivation). Erosion very variable, including significant areas of high and moderate erosion, but also very low in some areas.

Remarks Fire-protected gullies with AT 4 Gamtoos Thicket and a forest (dominated by *Ficus sur*) form an intricate mosaic with the fynbos. The boundary towards adjacent renosterveld is particularly indistinct and very broad, supporting communities of transitional character. The flatter, old African surfaces are dominated by *Cliffortia ruscifolia* and *Dodonaea viscosa* var. *angustifolia*.

References Cowling & Campbell (1983a, b), Cowling (1984), Cowling & Campbell (1984), Vlok & Euston-Brown (2002).

9.1.7 Alluvium Fynbos

Alluvium fynbos has previously been mapped as renosterveld. It covers relatively large blocks where there is a fine sediment talus adjacent to mountains in wetter areas. It is essentially a high-rainfall version of alluvium renosterveld, the major difference relating to the coarser nature of the sediments, the higher rainfall associated with elevated areas and adjacency to mountains and the consequent higher levels of leaching. It is also far wetter than can be gauged by its rainfall, as it is a conduit for

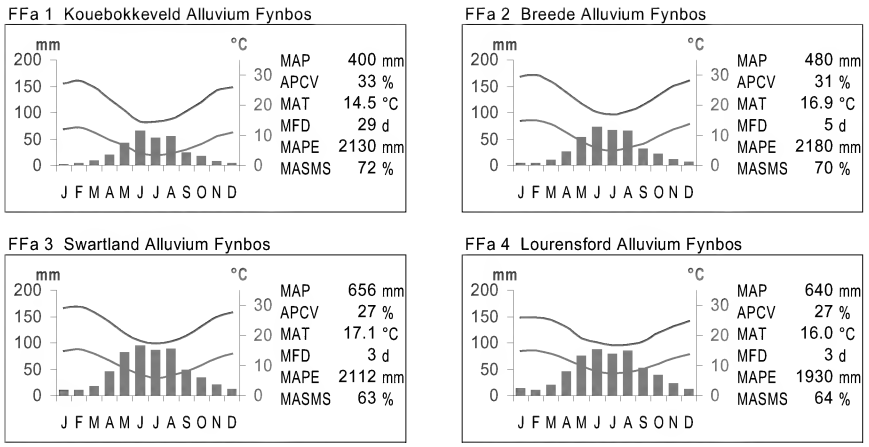

Figure 4.88 Climate diagrams of alluvium fynbos units. Blue bars show the median monthly precipitation. The upper and lower red lines show the mean daily maximum and minimum temperature respectively. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days (days when screen temperature was below 0°C); MAPE: Mean Annual Potential Evaporation; MASMS: Mean Annual Soil Moisture Stress (% of days when evaporative demand was more than double the soil moisture supply).

streams and rivers adjacent to mountains, which braid out in alluvial taluses before coalescing into the rivers of the plains. Floristically the alluvial fynbos therefore contains large portions of Restionaceae, Proteaceae and Ericaceae and classifies as true fynbos rather than renosterveld.

From its topographical position at the foot of the mountains, alluvium fynbos is well traversed with alluvial (riverine) vegetation patches, ranging from seeps to open to deep channels, with different amounts of colluvial rock. It also usually grades into adjacent shale fynbos units, but these have fine-grained sediments.

Typically the dominant communities are asteraceous, proteoid (*Leucadendron chamaelea*, *L. corymbosum* are prominent emergents) and restioid fynbos types. Considering its small aerial extent, some units are relatively rich in endemics, mainly bulbs, Fabaceae and Proteaceae. High levels of historical transformation may have resulted in high levels of extinction of endemics prior to intensive botanical collection. Still today, with the notable exception of FFa 3 Swartland Alluvium Fynbos (see Walton 2006) at Elandsberg Private Nature Reserve (north of Wellington), this is a poorly studied group of vegetation types.

FFa 1 Kouebokkeveld Alluvium Fynbos

VT 69 Macchia (100%) (Acocks 1953). Mesic Mountain Fynbos (31%), Central Mountain Renosterveld (17%), Dry Mountain Fynbos (6%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (81%) (Low & Rebelo 1996). BHU 47 Cederberg Mountain Fynbos Complex (47%), BHU 49 Swartruggens Mountain Fynbos Complex (35%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

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Figure 4.89 FFa 1 Kouebokkeveld Alluvium Fynbos: Restio-dominated fynbos with emergent *Protea laurifolia* on an alluvial fan at the foot of Hex River Mountains on the Farm Erfdeel in the Warm Bokkeveld, east of Ceres (Western Cape).

Distribution Western Cape Province: Fringes of the northern Koue Bokkeveld valleys from Op Die Berg (north of Ceres) northwards to Tandfontein and eastwards to Excelsior, extending to the Blinkberg Pass and Winkelhaak. Smaller unmapped patches are also found at north-facing entrances to valleys of the Hex River Mountains. Altitude 850–1 000 m.

Vegetation & Landscape Features Slightly undulating plains in mountain valleys where alluvium has accumulated alongside rivers and as alluvial fans. Vegetation is emergent proteoids in a low medium dense grassy shrubland, structurally primarily asteraceous and proteoid fynbos, with prominent ericaceous fynbos in numerous seeps.

Geology & Soils Sandy to silty alluvium with small cobbles embedded over Bokkeveld shales. Soils are duplex and dystrophic plinthic catenas and grey regic sands. Land types mainly Ca, Bb and Hb.

Climate Winter-rainfall climate with MAP 240–730 mm (mean: 400 mm), peaking from May to August. Mean daily maximum and minimum temperatures 28.0°C and 3.4°C for February and July, respectively. Frost incidence fairly infrequent, 10–30 days per year. This is the driest and coolest of all alluvium fynbos types due to the rainshadow effect and high elevation. See also climate diagram for FFa 1 Kouebokkeveld Alluvium Fynbos (Figure 4.88).

Important Taxa ([W]Wetlands) Tall Shrubs: *Protea laurifolia* (d), *Leucadendron chamelaea*, *Protea repens*. Low Shrubs: *Cliffortia amplexistipula*, *Elytropappus rhinocerotis*, *Erica muscosa*, *Leucadendron brunioides* var. *brunioides*, *L. glaberrimum* subsp. *glaberrimum*, *L. salignum*, *Protea laevis, Serruria cygnea*, *Spatalla caudata*[W], *Stoebe cinerea*, *S. plumosa*. Herb: *Dianthus bolusii*. Geophytic Herb: *Satyrium pumilum*. Graminoids: *Cymbopogon marginatus*, *Cynodon dactylon*, *Hyparrhenia hirta*, *Ischyrolepis capensis*.

Conservation Endangered. Target 29%. None statutorily conserved, with 1.4% conserved in Koue Bokkeveld mountain catchment area. Almost half of the area transformed for cultivation for orchards and pastures. Erosion very low and low.

Remarks This is a poorly studied vegetation unit. It grades into FFh 1 Kouebokkeveld Shale Fynbos as alluvium thins out.

Reference C. Boucher (unpublished data).

FFa 2 Breede Alluvium Fynbos

VT 69 Macchia (88%) (Acocks 1953). LR 61 Central Mountain Renosterveld (81%) (Low & Rebelo 1996). BHU 26 Breede Fynbos/Renosterveld Mosaic (54%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Upper Breede River Valley flats from Tulbagh to the Brandvlei Dam near Worcester including the Slanghoek and Brandwag Valleys, and extending to the Hex River Valley. Altitude 200–350 m, with few patches reaching altitudes as high as 600 m.

Vegetation & Landscape Features Slightly undulating plains and adjacent high mountains, with numerous alluvial fans and streams. Open emergent tall proteoids in a moderately tall shrub matrix with a graminoid understorey. Asteraceous and proteoid fynbos are dominant, with localised restioid fynbos and ericaceous fynbos.

Geology & Soils Quaternary alluvial deposits consisting of round cobbles embedded in fine loamy sand, over metasediments of the Malmesbury Group and Bokkeveld Group shales. Soils are usually of alluvial land type Ia, with some Fa land type

(with typical Glenrosa and Mispah forms). Hb and Ad land types also present.

Climate Seasonal, winter-rainfall climate peaking June–August. MAP 90–970 mm (mean: 480 mm). Mean daily maximum and minimum temperatures 29.9°C and 4.8°C for February and July, respectively. MAT close to 17°C. Frost incidence infrequent. Although in the rainshadow of the Hawequas Mountains, the area is well fed with water from the mountains. See also climate diagram for FFa 2 Breede Alluvium Fynbos (Figure 4.88).

Important Taxa ([T]Cape thickets, [W]Wetlands) Small Tree: *Protea nitida*. Tall Shrubs: *Diospyros glabra*[T], *Leucadendron chamelaea*, *L. rubrum*, *Leucospermum vestitum*, *Protea burchellii*, *P. laurifolia*, *P. repens*, *Rhus angustifolia*[T]. Low Shrubs: *Acmadenia matroosbergensis*, *Aspalathus spinosa* subsp. *flavispina*, *Athanasia trifurcata*, *Cliffortia ruscifolia*, *Leucadendron brunioides* var. *brunioides*, *L. corymbosum*, *L. salignum*, *Protea acaulos*, *Serruria fasciflora*, *Stoebe plumosa*. Herbs: *Adenogramma glomerata*, *Felicia tenella*. Geophytic Herbs: *Geissorhiza geminata*[W], *G. ornithogaloides* subsp. *ornithogaloides*. Graminoids: *Cynodon dactylon*, *C. incompletus*, *Ficinia indica*, *Hyparrhenia hirta*, *Ischyrolepis sieberi*, *Juncus cephalotes*, *Merxmuellera stricta*, *Pentaschistis airoides*, *Tetraria compar*, *Themeda triandra*, *Tribolium echinatum*.

Endemic Taxa ([W]Wetlands) Tall Shrub: *Leucadendron flexuosum*. Low Shrubs: *Aspalathus acanthoclada*, *A. amoena*, *A. singuliflora*, *A. tulbaghensis*, *Diastella parilis*, *Erica hansfordii*[W], *Leucadendron lanigerum* var. *laevigatum*, *L. spirale*, *Leucospermum calligerum* (prostrate form), *Rafnia crispa*. Succulent Shrub: *Lampranthus woodburniae*. Herb: *Manulea minor*. Geophytic Herbs: *Ixia mostertii*, *I. rouxii*, *Lachenalia moniliformis*, *Moraea worcesterensis*.

Conservation Endangered. Target 30%. Small patches conserved in the statutory Fonteintjiesberg and Limietberg Nature Reserves, Matroosberg and Hawequas (both mountain catchment areas) as well as in the private Quaggas Berg. Almost 60% already transformed for cultivation (vineyards, pastures, pine plantations), road building and urban sprawl. This area is susceptible to transformation through long-term continuous grazing and repeated short-interval burning. This disturbance eliminates palatable grasses and increases the unpalatable shrubs that sprout after fire or have a short life cycle. Aliens do not play a major role except for *Acacia saligna*, *Hakea sericea* and a number of alien annual grasses. Erosion very low and low.

Remarks This unit shares ecological and floristic features with FRa 1 Breede Alluvium Renosterveld, with which it grades to the east in the lower valleys. It also contains elements of the FFd 4 Atlantis Sand Fynbos, suggesting an ancient link, possibly as dune corridors over the Hawequas Mountains north of the Nuwekloof Pass.

References Boucher (1988b, 1994a).

FFa 3 Swartland Alluvium Fynbos

VT 69 Macchia (54%) (Acocks 1953). LR 62 West Coast Renosterveld (88%) (Low & Rebelo 1996). BHU 32 Boland Coast Renosterveld (89%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Swartland lowlands at west-facing piedmonts of the Groot Winterhoekberge near Porterville, Saronberg, Elandskloofberge to the Limietberge near Wellington; broad valley bottoms of the Paarl, Drakenstein, Franschhoek and Banhoek Valleys, with some extensions west of Paarl Mountain and to Klapmuts. Altitude 60–250 m, rarely reaching 350 m.

Vegetation & Landscape Features Moderately undulating plains, adjacent mountains and in river basins. The vegetation is a matrix of low, evergreen shrubland with emergent sparse, moderately tall shrubs and a conspicuous graminoid layer. Proteoid, restioid and asteraceous fynbos types are dominant, with closed-scrub fynbos common along the river courses. Ericaceous and restioid fynbos found in seeps.

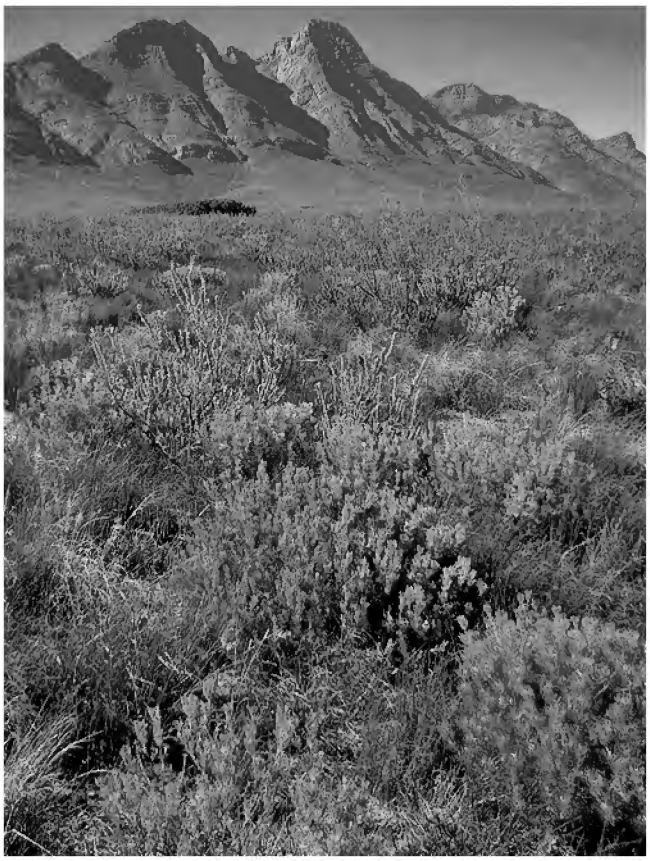
Geology & Soils Alluvial gravel and cobble fields typically resting over Malmesbury Group schists and phyllites (in the northern part of the area) as well as over Cape Suite granites (in Drakenstein Valley from Wellington to Franschhoek) and on Malmesbury Group sandstones from Simondium to Klipheuwel. Dominant land types Db (soils with prismacutanic and pedocutanic horizons) and Ga (soils with ferrihumic horizon).

Climate Seasonal, winter-rainfall regime, peaking from May to August. MAP (mean: 655 mm) varies broadly from 320–980 mm (close to foot of mountains). Mean daily maximum and minimum temperatures 29.5°C and 6.0°C for February and July, respectively. Frost an infrequent phenomenon. This is the wettest and hottest alluvium fynbos type. See also climate diagram for FFa 3 Swartland Alluvium Fynbos (Figure 4.88).

Important Taxa ([T]Cape thickets, [W]Wetlands) Tall Shrubs: *Diospyros glabra*[T] (d), *Olea europaea* subsp. *africana*[T] (d), *Psoralea aphylla* (d), *Rhus angustifolia*[T] (d), *Dodonaea viscosa* var. *angustifolia*, *Metalasia densa*, *Morella cordifolia*, *Passerina corymbosa*, *Phylica buxifolia*, *Protea repens*, *Rhus incisa*[T], *Rubus rigidus*. Low Shrubs: *Cliffortia ferruginea* (d), *Elytropappus rhinocerotis* (d), *Eriocephalus africanus* var. *africanus* (d), *Leucadendron corymbosum* (d), *Leucospermum calligerum* (d), *Passerina truncata* subsp. *truncata* (d), *Senecio halimifolius* (d), *Serruria candicans* (d), *Athanasia trifurcata*, *Cliffortia juniperina*, *C. ruscifolia*, *Elytropappus gnaphaloides*,

L. Mucina

Figure 4.90 FFa 2 Breede Alluvium Fynbos: Proteoid fynbos dominated by *Leucadendron salignum* with emergent *Cliffortia ruscifolia* near Worcester (Western Cape).



L. Mucina

Figure 4.91 FFa 3 Swartland Alluvium Fynbos: Proteoid fynbos with *Leucospermum calligerum* and *Serruria candicans* (foreground) and *Leucadendron corymbosum* (background) on alluvial fans in the Elandsberg Private Nature Reserve north of Wellington (Western Cape).

Euryops pinnatipartitus, *Galenia africana*, *Leucadendron lanigerum* var. *lanigerum*, *L. salignum*, *L. stellare*, *Oftia africana*, *Plecostachys serpyllifolia*, *Stoebe plumosa*, *Trichocephalus stipularis*. Woody Climber: *Microloma sagittatum*. Herbs: *Conyza pinnatifida*, *Corymbium africanum*, *Dischisma arenarium*, *Lebeckia sepiaria*. Geophytic Herbs: *Pteridium aquilinum* (d), *Zantedeschia aethiopica*[W] (d), *Geissorhiza imbricata* subsp. *bicolor*[W], *G. setacea*, *Mohria caffrorum*, *Oxalis goniorrhiza*, *Spiloxene flaccida*. Herbaceous Climber: *Dipogon lignosus*. Graminoids: *Calopsis paniculata* (d), *Cynodon dactylon* (d), *Elegia filacea* (d), *Ficinia brevifolia* (d), *Ischyrolepis capensis* (d), *I. tenuissima* (d), *Juncus capensis* (d), *Merxmuellera cincta* (d), *Calopsis rigorata*, *Cannomois parviflora*, *Elegia nuta*, *E. recta*, *Eragrostis curvula*, *Pentaschistis curvifolia*, *P. pallida*, *Pycreus polystachyos*[W], *Restio filiformis*, *Thamnochortus fruticosus*, *T. punctatus*, *Willdenowia glomerata*, *W. incurvata*, *W. sulcata*, *W. teres*.

Endemic Taxa ([W]Wetlands) Low Shrubs: *Diastella buekii*, *Erica alexandri*, *E. bakeri*[W], *Marasmodes duemmeri*, *M. undulata*, *Phylica stenopetala*, *Protea mucronifolia*. Succulent Shrub: *Lampranthus schlechteri*. Geophytic Herbs: *Brunsvigia elandsmontana*, *Bulbine monophylla*, *Geissorhiza furva*, *Moraea villosa* subsp. *elandsmontana*.

Conservation Critically endangered. Target 30%. Nearly 10% conserved in the Waterval Nature Reserve, Winterhoek (mountain catchment area) and private reserves such as Elandsberg, Langerug and Wiesenhof Wildpark. More than 75% already transformed for vineyards, olive orchards, pine plantations, urban settlements and by building of the Voëlvlei and Wemmershoek Dams. Alien *Acacia saligna* and *Hakea sericea* are prominent in places. Erosion moderate and very low.

Remarks Previously this was considered to be part of renosterveld (e.g. Moll & Bossi 1983, Low & Rebelo 1996), but it is clearly a fynbos type. This unit forms a complicated mosaic with FRs 9 Swartland Shale Renosterveld at its lower extremity, and some of the communities have an ecotonal character, for example where the soils are dominated by clay-rich silts.

References Boucher (1983, 1987), Jones (1986), Diemer (2000), Walton (2006), N. Helme (unpublished data).

FFa 4 Lourensford Alluvium Fynbos

VT 47 Coastal Macchia (52%) (Acocks 1953). LR 62 West Coast Renosterveld (46%), LR 68 Sand Plain Fynbos (29%), LR 64 Mountain Fynbos (21%) (Low & Rebelo 1996). BHU 32 Boland Coast Renosterveld (42%), BHU 12 Blackheath Sand Plain Fynbos (30%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Low-lying areas between Firgrove and Gordon's Bay, including much of the Strand and Somerset West, extending up the Lourens River Valley to the Sawmill above Lourensford Estate. Altitude 20–150 m.

Vegetation & Landscape Features Low-lying plains supporting low, medium dense shrubland with short graminoid understorey. Restioid and asteraceous fynbos are dominant, although there is some evidence that proteoid fynbos might once have been dominant. Some remnants are exceptionally rich in geophytes.

Geology & Soils Plinthic, duplex, silty soils often with small cobbles and pebbles embedded. Found over Cape Suite granite and metasediments of the Tygerberg Formation (Malmesbury Group). Land types mainly Ca and Ac.

Climate Winter-rainfall climate peaking from May to August. MAP 470–980 mm (mean: 640 mm). Mean daily maximum and minimum temperatures 26.0°C and 7.4°C for February and July, respectively. Frost incidence infrequent. This is the only alluvium fynbos under strong maritime influence. See also climate diagram for FFa 4 Lourensford Alluvium Fynbos (Figure 4.88).

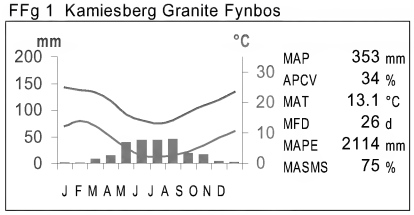
Important Taxa Small Tree: *Protea nitida*. Tall Shrubs: *Protea burchellii*, *P. coronata*, *P. repens*. Low Shrubs: *Asparagus rubicundus*, *Athanasia juncea*, *A. trifurcata*, *Cliffortia marginata*, *Erica imbricata*, *E. paniculata*, *Leucadendron lanigerum* var. *lanigerum*, *L. salignum*, *Lotononis prostrata*, *Marasmodes polycephala*, *Protea cynaroides*, *P. scolymocephala*, *Senecio pubigerus*, *Stoebe plumosa*. Herb: *Helichrysum crispum*. Geophytic Herbs: *Ammocharis longifolia*, *Geissorhiza setacea*, *Ixia dubia*. Graminoids: *Cymbopogon marginatus*, *Cynodon dactylon*, *Elegia recta*, *Ficinia indica*, *Hyparrhenia hirta*, *Ischyrolepis capensis*, *Staberoha cernua*, *Tetraria compar*, *Themeda triandra*, *Tribolium uniolae*.

Conservation Critically endangered. About 3% conserved in the Helderberg and Harmony Flats Nature Reserves and a further 22% in Lourens River (protected natural area). The conservation target of 30% is unattainable since more than 90% of the area has been transformed for urban development (Helderberg Municipality), cultivation, pine plantations and roads. Erosion very low and moderate.

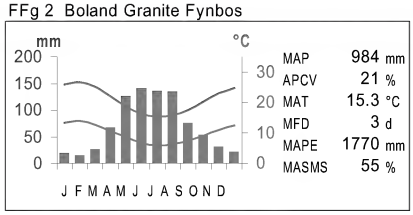
Remarks This unit falls within areas farmed since earliest colonial times (Farm Vergelegen of W.A. van der Stel since 1700). Most of the remnants are transformed by grazing, mowing and changes in fire regime, and it is uncertain what has been lost and whether the remaining patches are representative of the original vegetation type.

References C. Boucher (unpublished data), N. Helme (unpublished data).

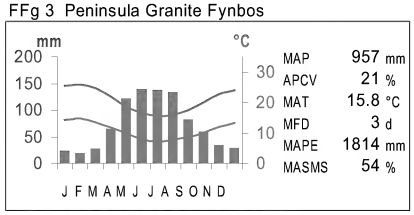
FFg 1 Kamiesberg Granite Fynbos



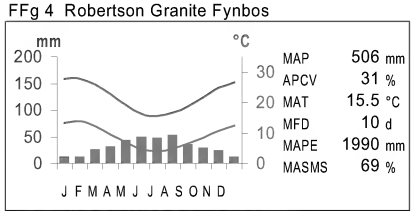
FFg 2 Boland Granite Fynbos



FFg 3 Peninsula Granite Fynbos



FFg 4 Robertson Granite Fynbos



FFg 5 Garden Route Granite Fynbos

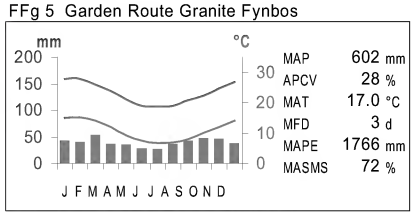


Figure 4.92 Climate diagrams of granite fynbos units. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days; MAPE: Mean Annual Potential Evaporation; MASMS: Mean Annual Soil Moisture Stress.

9.1.8 Granite Fynbos

Granite fynbos occurs on only 2% of the area of fynbos vegetation. It has two major facies. In wetter areas on steeper slopes it is usually on a deep, well-drained soil, prone to further erosion by large dongas that extend from a watercourse upslope of the base of the overlying sandstone cliffs. These usually have pure fynbos communities, although in screes and canalised watercourses, closed-scrub fynbos and Cape thicket occur. In drier areas and areas of harder rock, large granite domes are prominent, with pockets of deep soil. Here, in relatively fire-safe environments, the Cape thicket element is dominant on the lower edges of the boulders, within boulder fields and in gullies, with fynbos in the open areas in between. In addition, rock communities are prominent, and characteristically support a succulent flora.

Granite fynbos is characteristically tall and dense, often with *Cliffortia* and other spiny-leaved species. Floristically and structurally this type shares most elements with shale fynbos, except for the dominance of patches of closed-scrub fynbos and Cape thicket elements. Being more fertile than sandstone fynbos, granite fynbos has a very distinctive post-fire seral phase dominated by dense 1–1.5 m tall stands of Asteraceae and Fabaceae, primarily *Aspalathus*. These stands last for two to three years before they die away and the asteraceous, restioid and proteoid fynbos grow through and become dominant. Structurally this vegetation is taller and denser than typical fynbos. Drier slopes support asteraceous fynbos, dominated by spine-leaved species and large resprouting shrubs, whereas proteoid fynbos is dominant in wetter areas. Waboomveld is dominant in the mid-lower slopes.

FFg 1 Kamiesberg Granite Fynbos

VT 69 Macchia (75%) (Acocks 1953). LR 64 Mountain Fynbos (74%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Namaqualand, summits and upper slopes of Rooiberg in the north (1 395 m) on the Farm Pedroskloof, Sneeukop (1 589 m), Kamiesberg (1 527 m), Johannes se Berg (1 550 m), Sittenberg (1 553 m), Eselkop (1 664 m) and Rooiberg (1 705 m) south of Rhebokskloof in the south, in the Kamiesberg Mountains (roughly in the area between Kamieskroon, Leliefontein and Garies). Rather anomalously, the unit is not very strongly correlated with altitude. Although the low altitude limit is roughly 1 450 m, outliers occur as low as 1 200 m including some sporadic occurrences on flats between the mountains. It is absent from many areas above 1 200 m in the region. The upper altitude limit is the summit of Rooiberg (1 705 m), the highest peak in Namaqualand.

Vegetation & Landscape Features System of round-top mountains and broad-shoulder ridges dominated by granite domes and slabs. The dominant vegetation is usually medium tall (1–2 m), sparse (cover 30–40%, up to 60%) shrubland dominated by malacophyllous shrubs. In structural terms this shrubland ranks as asteraceous fynbos. Localised patches of fynbos may occur lower in the landscape within renosterveld in seepages and in alluvial washes. When heavily grazed, this vegetation type is transformed into karoo, resulting in fence-line contrasts of succulent karoo shrubs versus asteraceous fynbos. When burned or bush-cut, the annual and bulb flora result in spectacular displays.

Geology & Soils Granites and gneisses of the Mokolian Kamieskroon Gneiss and Stalhoek Complex. Soils skeletal, shallow and sandy, typical of Ic land type.

Climate Precipitation low, with the lowest average values at the semi-arid limit. MAP 240–450 mm (mean: 355 mm), peaking from May to August. This type is near the lower-rainfall limits for fynbos on granite, and is the driest of the granite types. Mean daily maximum and minimum temperatures 24.9°C and 2.1°C for January and July, respectively. Frost incidence 10–40 days per year. See also climate diagram for FFg 1 Kamiesberg Granite Fynbos (Figure 4.92).

Important Taxa Low Shrubs: *Erica plukenetii* subsp. *plukenetii* (d), *Metalasia densa* (d), *Anginon difforme*, *Anthospermum spathulatum* subsp. *spathulatum*, *Arctotis revoluta*, *Chrysanthemoides monilifera* subsp. *pisiformis*, *Cliffortia ruscifolia*, *Diosma hirsuta*, *Euryops tenuissimus*, *Lobostemon glaucophyllus*, *Passerina truncata* subsp. *truncata*, *Phylica cryptandroides*, *P. montana*, *Selago glutinosa* subsp. *glutinosa*. Herbs: *Heliophila schulzii*, *Peucedanum khamiesbergense*. Geophytic Herb: *Gladiolus hyalinus*. Graminoids: *Calopsis marlothii*, *C. viminea*, *Ischyrolepis gossypina*, *I. ocreata*, *I. rottboellioides*, *I. sieberi*, *Restio cymosus*.

Biogeographically Important Taxa (all Kamiesberg endemics) Low Shrubs: *Aspalathus angustifolia* subsp. *robusta*, *Muraltia rigida*. Herbs: *Centella tridentata* var. *dregeana, Lotononis acutiflora*. Geophytic Herb: *Hesperantha latifolia*.

Endemic Taxa ([W]Wetlands) Low Shrubs: *Agathosma namaquensis*, *Amphithalea obtusiloba*, *Cullumia rigida*, *Lotononis magnifica*, *Oedera conferta*, *Phylica retrorsa*, *Protea namaquana*, *Vexatorella alpina*. Herbs: *Hebenstretia kamiesbergensis*, *Peucedanum pearsonii*. Geophytic Herbs: *Gladiolus kamiesbergensis*, *Hesperantha minima*, *Oxalis creaseyi*, *Romulea rupestris*, *Watsonia rourkei*, *Xenoscapa uliginosa*[W]. Succulent Herb:

L. Mucina

Figure 4.93 FFg 1 Kamiesberg Granite Fynbos: Dry asteraceous fynbos with *Agathosma namaquana, Metalasia densa* and *Ischyrolepis sieberi* on a granite dome of the Rooiberg (1 706 m) in the Kamiesberg Mountains, Namaqualand (Northern Cape).

Conophytum khamiesbergense. Graminoids: *Ischyrolepis vilis*, *Pentaschistis lima*.

Conservation Least threatened. Target 27%. None conserved in statutory or private conservation areas. Only about 2% transformed (cultivation), but much of the 'natural veld' is degraded by heavy grazing. Erosion is moderate.

Remark 1 The proteoid affinities of this vegetation are with derived elements in quartzitic fynbos, suggesting that only arid-adapted species crossed the Krom River gap to the south. Some fynbos elements (e.g. *Erica plukenetii*, *Ischyrolepis sieberi*) occur well north of Kamiesberg in the Springbok area, but in these habitats these 'tramp' species are generally found as a rare admixture within a matrix of renosterveld.

Remark 2 The FFg 1 Kamiesberg Granite Fynbos is embedded within the FRg 1 Namaqualand Granite Renosterveld. These two vegetation units form the core of the Kamiesberg Centre of Endemism (Van Wyk & Smith 2001). The lower boundary of the granite fynbos with renosterveld is complex and the transition varies. In places it is clear-cut, but in other areas broad transition zones can be found, with fynbos elements persisting within renosterveld in rocky and moist facies, and renosterveld elements found on the deeper soils within fynbos. The large bare slabs of granite support small and shallow-soil grit pans filled with coarse granite sand. These habitats as well as crevices in the granite slabs contain lithophytic communities dominated by *Polymita albescens, Othonna euphorbioides*, and many other succulent taxa (*Anacampseros, Conophytum, Cotyledon, Crassula* etc.) and geophytes. These patches of vegetation should be classified within the SKn 1 Namaqualand Klipkoppe Shrubland (see also the Chapter on Succulent Karoo).

References Adamson (1958), Van Wyk & Smith (2001), N. Helme (unpublished data), L. Mucina (unpublished data).

FFg 2 Boland Granite Fynbos

VT 69 Macchia (82%) (Acocks 1953). Mesic Mountain Fynbos (56%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (59%) (Low & Rebelo 1996). BHU 32 Boland Coast Renosterveld (41%), BHU 54 Franschhoek Mountain Fynbos Complex (29%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Upper slopes and summits of Paardeberg and Paarl Mountain as well as the lower slopes of mountains spanning the Groenberg and Hawequasberge (western foothills near Wellington), Pniel (Simonsberg and Groot Drakenstein Mountains and Klapmutskop), Franschhoek (Middelberg, Dassenberg, Skerpheuwel, Middagkransberg), Stellenbosch (Jonkershoek Valley and northern side of the Helderberg) and Helderberg Municipality (including lower south- and west-facing slopes of Haelkop and the Hottentots Holland Mountains and also the free-standing Skapenberg). It also occurs in the Du Toitskloof and Wemmershoek Valleys, Kaaimansgat and lower Stettynskloof, with outcrops on the Bottelary Hills and Kanonkop (near Pella). Altitude 150–650 m, reaching 850 m in places.

Vegetation & Landscape Features Moderately undulating plains and hills, varying from extensive deep soils, to localised deep soils between large granite domes and sheets. A fairly dense, 1–2 m tall closed shrubland with occasional low, gnarled trees dotted through the landscape. A diverse type, dominated by scrub, asteraceous and proteoid fynbos (with *Protea repens, P. burchelli, P. laurifolia* with *Leucadendron rubrum* and *L. daphnoides* as dominants on drier slopes, *Leucospermum grandiflorum* or *L. gueinzii* dominant in seepage areas, and *P. neriifolia* and *Leucadendron sessile* on moist slopes), but with patches of restioid and ericaceous fynbos in wetter areas. Waboomveld is very typical and very extensive within this unit.

Geology & Soils Cape Granite Suite rocks (Paardeberg, Paarl, Stellenbosch and Wellington Plutons). Soils usually of Glenrosa,

L. Mucina

Figure 4.94 FFg 2 Boland Granite Fynbos: Proteoid fynbos dominated by *Protea burchellii* and *Leucadendron salignum* below granite domes of the Paarl Mountain near Paarl (Western Cape).

Mispah forms, or red-yellow apedal. Freely draining soils are dominant, with exposed dome rock and large boulders. Land types mainly Fa, Ic and Ac.

Climate MAP 610–2 220 mm (mean: 985 mm), peaking from May to August. Mean daily maximum and minimum temperatures 26.6°C and 5.9°C for February and July, respectively. Frost incidence 2 or 3 days per year. The mean rainfall for this type is well below the 1 400 mm limit suggested by Campbell (1985) for fynbos on granite. Mists are common in winter. See also climate diagram for FFg 2 Boland Granite Fynbos (Figure 4.92).

Important Taxa ([T]Cape thickets, [W]Wetlands) Small Trees: *Protea nitida* (d), *Brabejum stellatifolium*[T], *Heeria argentea*[T], *Leucospermum conocarpodendron* subsp. *viridum*, *Podocarpus elongatus*[T]. Tall Shrubs: *Cliffortia cuneata* (d), *Diospyros glabra*[T] (d), *Euclea racemosa* subsp. *racemosa*[T] (d), *Leucadendron rubrum* (d), *Olea europaea* subsp. *africana*[T] (d), *Protea neriifolia* (d), *P. repens* (d), *Putterlickia pyracantha*[T] (d), *Rhus angustifolia*[T] (d), *R. laevigata*[T] (d), *Cassine schinoides*[T], *Chrysanthemoides monilifera*, *Cliffortia phillipsii*, *Cunonia capensis*[T], *Dodonaea viscosa* var. *angustifolia*, *Euryops abrotanifolius*, *Gymnosporia buxifolia*, *Halleria lucida*[T], *Maytenus acuminata*[T], *Montinia caryophyllacea*, *Myrsine africana*[T], *Passerina corymbosa*, *Podalyria myrtillifolia*, *Protea burchellii*, *Rapanea melanophloeos*[T], *Rhus glauca*[T], *R. lucida*[T], *R. tomentosa*[T], *Wiborgia obcordata*. Low Shrubs: *Anthospermum aethiopicum* (d), *Berzelia lanuginosa*[W] (d), *Brunia nodiflora* (d), *Cliffortia ruscifolia* (d), *Elytropappus rhinocerotis* (d), *Erica muscosa* (d), *E. plukenetii* subsp. *plukenetii* (d), *Eriocephalus africanus* var. *africanus* (d), *Helichrysum teretifolium* (d), *Leucadendron salignum* (d), *Osmitopsis asteriscoides*[W] (d), *Salvia lanceolata* (d), *Agathosma imbricata*, *A. serpyllacea*, *Aspalathus bracteata*, *A. elliptica*, *A. lebeckioides*, *Cliffortia dentata*, *Clutia pubescens*, *Erica abietina* subsp. *aurantiaca*, *E. hispidula*, *E. imbricata*, *E. sphaeroidea*, *Eriocephalus africanus* var. *paniculatus*, *Euclea tomentosa*[T], *Euphorbia genistoides*, *Euryops thunbergii*, *Helichrysum zeyheri*, *Hermannia cuneifolia*, *H. scabra*, *Leucadendron daphnoides*, *L. sessile*, *Microdon dubius*, *Muraltia decipiens*, *Otholobium obliquum*, *O. rotundifolium*, *Pelargonium tabulare*, *Phylica thunbergiana*, *Printzia polifolia*, *Protea acaulos*, *P. scorzonerifolia*, *Salvia africana-lutea*, *Serruria kraussii*, *Stoebe plumosa*, *Ursinia paleacea*, *Xiphotheca lanceolata*. Succulent Shrubs: *Aloe perfoliata*, *Antimima granitica*, *Lampranthus spiniformis*, *Tetragonia spicata*. Woody Climbers: *Asparagus scandens*, *Microloma sagittatum*, *Secamone alpini*, *Zygophyllum sessilifolium*. Semiparasitic Shrub: *Thesium funale*. Herbs: *Annesorhiza macrocarpa*, *Corymbium scabrum*, *Galium mucroniferum*, *Gazania ciliaris*, *Helichrysum crispum*, *Knowltonia vesicatoria*, *Lichtensteinia obscura*, *Mairia burchellii*, *Nemesia affinis*, *Polycarena capensis*, *Pseudoselago serrata*, *Senecio arenarius*, *Tripteris tomentosa*, *Wimmerella bifida*[W]. Geophytic Herbs: *Aristea capitata* (d), *Pteridium aquilinum* (d), *Blechnum australe*, *Bobartia indica*, *Cyphia phyteuma*, *Lachenalia aloides*, *Lapeirousia corymbosa*, *Moraea galaxia*, *Oxalis bifida*, *Romulea hirsuta*, *Rumohra adiantiformis*, *Spiloxene serrata*, *Trachyandra filiformis*, *Wachendorfia paniculata*, *Watsonia borbonica* subsp. *borbonica*, *Zantedeschia aethiopica*[W]. Herbaceous Climber: *Cynanchum africanum*. Graminoids: *Cymbopogon marginatus* (d), *Ehrharta calycina* (d), *E. villosa* var. *villosa* (d), *Elegia asperiflora* (d), *Ischyrolepis capensis* (d), *I. gaudichaudiana* (d), *Merxmuellera cincta* (d), *M. rufa* (d), *M. stricta* (d), *Restio filiformis* (d), *Tetraria fasciata* (d), *Aristida vestita*, *Cannomois virgata*, *Ehrharta ottonis*, *Eragrostis curvula*, *Ficinia indica*, *F. nigrescens*, *F. trichodes*, *Hyparrhenia hirta*, *Ischyrolepis sieberi*, *Neesenbeckia punctoria*, *Pentaschistis aristidoides*, *Platycaulos depauperatus*, *Schoenoxiphium ecklonii*, *S. lanceum*, *Tetraria bromoides*, *T. burmannii*, *T. sylvatica*, *Themeda triandra*, *Willdenowia incurvata*.

Endemic Taxa Tall Shrub: *Leucospermum grandiflorum*. Low Shrubs: *Aspalathus cephalotes* subsp. *cephalotes*, *A. stricticlada*, *Erica fausta*, *E. hippurus*, *E. lerouxiae*, *E. setosa*, *Leucospermum lineare*, *Lobostemon hottentoticus*, *Psoralea gueinzii*, *Pteronia centauroides*, *Serruria gracilis*, *Xiphotheca elliptica*. Succulent Shrubs: *Erepsia lacera*, *Lampranthus leptaleon*, *L. rupestris*, *Oscularia paardebergensis*. Herb: *Argyrolobium angustissimum*. Geophytic Herbs: *Babiana noctiflora*, *Ixia cochlearis*, *Lapeirousia azurea*, *Watsonia amabilis*. Succulent Herb: *Conophytum turrigerum*.

Conservation Endangered. Target 30%. Some 14% statutorily conserved in the Hawequas, Hottentots Holland and Paarl Mountain Nature Reserves, with a further 34% found in Hawequas, Hottentots Holland mountain catchment areas and Helderberg and Paardenberg Nature Reserves. More than half of the area has been transformed for vineyards, olive groves and pine plantations. Most common woody aliens include *Pinus pinaster, Hakea sericea* and *Acacia saligna*. Erosion very low and moderate.

Remark 1 Many species common to this unit are shared with FFh 5 Cape Winelands Shale Fynbos, to which this unit is closely related—the two share many endemics (e.g. *Leucadendron daphnoides*, *Leucospermum gueinzii*, *Serruria kraussii*). Although many species are shared, granite fynbos extends to lower rainfall than shale fynbos does (although the mean is higher due to higher relief of granite), so that species found in narrow, upper zones within shale fynbos are often quite widespread in granite fynbos.

Remark 2 Cape thicket and occasionally also forest patches occur within fire-protected sites against the granite outcrops, on sandstone rock-fall screes and in steeper river courses. Succulent and geophytic 'gardens' (*Oscularia* and *Crassula* are well represented here) are found on extensive granite domes and slabs which also support epilithic lichen flora.

References Adamson (1927), Duthie (1929), Acocks (1935), Rycroft (1953), Van der Merwe (1962, 1966), Werger et al. (1972a, b), Kruger (1979), Boucher (1983, 1987, 1988b, 1994a, 1996b, 1997a), McDonald (1985, 1987, 1988), Neethling (1986), Le Maitre (1987), Sieben (2003), N. Helme (unpublished data).

FFg 3 Peninsula Granite Fynbos

VT 69 Macchia (74%) (Acocks 1953). LR 64 Mountain Fynbos (53%) (Low & Rebelo 1996). BHU 55 Cape Peninsula Mountain Fynbos Complex (63%), BHU 12 Blackheath Sand Plain Fynbos (36%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Lower slopes on the Cape Peninsula from Lion's Head to Smitswinkel Bay almost completely surrounding Table Mountain, Karbonkelberg and Constantiaberg through to the Kalk Bay Mountains. South of the Fish Hoek gap, it is limited to the eastern (False Bay) side of the Peninsula from Simon's Bay to Smitswinkel Bay, with a few small patches between Fish Hoek and Ocean View. Altitude 0–450 m.

Vegetation & Landscape Features Steep to gentle slopes below the sandstone mountain slopes, and undulating hills on the western edge of the Cape Flats. Medium dense to open trees in tall, dense proteoid shrubland. A diverse type, dominated by asteraceous and proteoid fynbos, but with patches of *Restio* and ericaceous fynbos in wetter areas. Waboomveld is extensive in the north and heavily encroached by afrotemperate forest in places. South of Hout Bay, the dwarf form of *Protea nitida* is dominant, so that there are no emergent proteoids.

L. Mucina

Figure 4.95 FFg 3 Peninsula Granite Fynbos: Ericaceous fynbos housing seven *Erica* species (with *E. ericoides* and *E. glabella* dominating) and *Pelargonium cucullatum* on the eastern slopes of Table Mountain in Kirstenbosch National Botanical Garden, Cape Town. A small, fire-protected grove of *Widdringtonia nodiflora* is visible in the background.

Groves of Silver Trees (*Leucadendron argenteum*) occur on the wetter slopes.

Geology & Soils Deep loamy, sandy soils, red-yellow apedal or Glenrosa and Mispah forms, derived from Cape Peninsula Pluton of the Cape Granite Suite. Land types mainly Ac, Fa and Bc.

Climate Typical winter-rainfall climate peaking from May to August. MAP 590–1 320 mm (mean: 960 mm). Mean daily maximum and minimum temperatures 26.0°C and 7.2°C for February and July, respectively. Frost incidence 2 or 3 days per year. The climate of this unit is almost identical to that of FFg 2 Boland Granite Fynbos, but shows a far stronger maritime influence. See also climate diagram for FFg 3 Peninsula Granite Fynbos (Figure 4.92).

Important Taxa ([T]Cape thickets, [W]Wetlands) Small Trees: *Brabejum stellatifolium*[T] (d), *Kiggelaria africana*[T] (d), *Leucadendron argenteum* (d), *Protea nitida* (d), *Widdringtonia nodiflora* (d), *Leucospermum conocarpodendron* subsp. *conocarpodendron*. Tall Shrubs: *Diospyros whyteana*[T] (d), *Leucadendron rubrum* (d), *Metalasia densa* (d), *Passerina corymbosa* (d), *Podalyria calyptrata* (d), *Protea coronata* (d), *P. lepidocarpodendron* (d), *Rhus lucida*[T] (d), *R. tomentosa*[T] (d), *Cassine peragua* subsp. *peragua*[T], *Chrysanthemoides monilifera*, *Euryops abrotanifolius*, *Montinia caryophyllacea*, *Myrsine africana*[T], *Psoralea aphylla*, *P. pinnata*[W], *Putterlickia pyracantha*[T], *Rhus laevigata*[T]. Low Shrubs: *Cliffortia stricta* (d), *Elytropappus gnaphaloides* (d), *E. rhinocerotis* (d), *Erica hirtiflora* (d), *E. plukenetii* subsp. *plukenetii* (d), *Leucadendron salignum* (d), *L. xanthoconus* (d), *Stoebe cinerea* (d), *Anthospermum aethiopicum*, *Aspalathus astroites*, *Berzelia lanuginosa*[W], *Brunia nodiflora*, *Cliffortia drepanoides*, *C. ruscifolia*, *Clutia polifolia*, *Erica baccans*, *E. ericoides*, *E. mauritanica*, *Eriocephalus racemosus*, *Euryops pinnatipartitus*, *Felicia aethiopica*, *Heliophila callosa*, *Maytenus oleoides*[T], *Morella quercifolia*, *Osteospermum ciliatum*, *Otholobium fruticans*, *Pelargonium cucullatum*, *Penaea mucronata*, *Phylica imberbis*, *Psoralea lucida*, *Stilbe vestita*, *Stoebe alopecuroides*, *S. fusca*, *Trichocephalus stipularis*. Semiparasitic Shrub: *Osyris compressa*. Herbs: *Edmondia sesamoides*, *Pseudoselago spuria*. Geophytic Herbs: *Aristea bakeri* (d), *A. capitata* (d), *Pteridium aquilinum* (d), *Amaryllis belladonna*, *Geissorhiza pusilla*, *Romulea cruciata*. Graminoids: *Cannomois virgata* (d), *Ischyrolepis eleocharis* (d), *I. gaudichaudiana* (d), *Mastersiella digitata* (d), *Restio triticeus* (d), *Cymbopogon marginatus*, *Elegia racemosa*, *Ficinia angustifolia*, *F. filiformis*, *F. oligantha*, *Hypodiscus albo-aristatus*, *Restio filiformis*, *Thamnochortus erectus*.

Endemic Taxa Low Shrubs: *Cliffortia carinata*, *Gnidia parvula*, *Hermannia micrantha*, *Leucadendron grandiflorum*. Succulent Shrubs: *Erepsia patula*, *Lampranthus curvifolius*. Herb: *Polycarena silenoides*. Geophytic Herb: *Aristea pauciflora*. Graminoid: *Willdenowia affinis*.

Conservation Endangered. Target 30%. Conserved in the Table Mountain National Park as well as on the premises of the Kirstenbosch National Botanical Garden. However, much of the conserved fynbos has been transformed into afrotemperate forest due to fire protection policies at Orangekloof and Kirstenbosch and a reluctance to use fire in green belts and on the urban fringe. The effective fynbos area conserved is thus much lower. A total of 56% transformed, mostly Cape Town urban areas (40%) on low-lying flat areas, including vineyards and pine plantations (13%). The most common alien woody species include *Acacia melanoxylon*, *Pinus pinaster* and numerous other more localised invasive alien species, reflecting the long history of colonisation and the relatively fertile soils. Erosion is very low.

Remarks Although well studied, published knowledge is largely confined to Kirstenbosch and Orangekloof. There are almost no data for the eastern and northern slopes of Table Mountain, and none for the area south of Constantia Neck. The northern tip of this unit was visited by the much venerated Charles Darwin in 1844 at the point of contact of the granite with the neighbouring shale.

References Adamson (1925, 1927, 1935), McKenzie (1976), McKenzie et al. (1977), Jeffrey & Wilson (1987), Tritton (1992), Lotz (1993), Simmons (1996).

FFg 4 Robertson Granite Fynbos

VT 69 Macchia (56%) (Acocks 1953). Central Mountain Renosterveld (57%) (Moll & Bossi 1983). LR 61 Central Mountain Renosterveld (58%) (Low & Rebelo 1996). BHU 38 Ashton Inland Renosterveld (58%), BHU 64 Southern Langeberg Mountain Fynbos Complex (26%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Confined to southern foothills of the Langeberg, namely the higher parts of Tierberg northwest of Robertson and the Langeberg from the Kabous River at Bergenheim to Bakoondshoogte west of Swellendam. Altitude 250–400 m for the belt near Swellendam, and 550–949 m at Graanpunt, the summit of Tierberg.

Vegetation & Landscape Features Steep, undulating hills covered with a dense proteoid shrubland, or shrubland with high grass cover. Structurally it is mostly graminoid and proteoid fynbos.

Geology & Soils Deep loamy sands, Glenrosa and Mispah forms, derived from Cape Granites (Robertson and Dassenheuwel Plutons of Cambrian age). Land types mainly Fb and Fa.

Climate MAP 190–1 000 mm (mean: 505 mm), peaking from May to August. Mean daily maximum and minimum tempera-

tures 27.8°C and 4.0°C for January–February and July, respectively. Frost incidence 5–10 days per year. See also climate diagram for FFg 4 Robertson Granite Fynbos (Figure 4.92).

Important Taxa Tall Shrubs: *Protea neriifolia* (d), *Euryops abrotanifolius*, *Leucadendron eucalyptifolium*, *L. rubrum*, *Metalasia densa*. Low Shrubs: *Anthospermum galioides* subsp. *galioides* (d), *A. spathulatum* subsp. *spathulatum* (d), *Hermannia alnifolia* (d), *Athanasia trifurcata*, *Cliffortia erectisepala*, *Clutia marginata*, *Erica plukenetii* subsp. *plukenetii*, *E. setacea*, *Eriocephalus africanus* var. *africanus*, *Gnidia laxa*, *Leucadendron salignum*, *L. spissifolium* subsp. *spissifolium*, *Muraltia ericaefolia*, *Protea nitida* (dwarf form). Herb: *Berkheya armata*. Graminoids: *Ehrharta calycina* (d), *E. thunbergii* (d), *Merxmuellera stricta* (d), *Themeda triandra* (d).

Conservation Least threatened. Target 30%. About 2% statutorily conserved in the Dassieshoek Nature Reserve as well as (about 39%) in Langeberg-wes mountain catchment area. More than 10% already transformed for cultivation (pastures and vineyards). Aliens *Acacia saligna* and *Pinus pinaster* are of local concern. Erosion moderate and very low.

Remarks This is an almost completely unknown, isolated unit, conspicuous from afar because of its grassy nature. An additional small area in the Riviersonderend Mountains southwest of Pilaarkop, classified as FFh 7 Greyton Shale Fynbos, is also on Cape Granite, but it is predominantly covered by afrotemperate forest. The two areas share curious disjunct populations of *Leucospermum formosum*, but in both cases this species occurs on the shales adjacent to these patches.

Reference N. Helme (unpublished data).

FFg 5 Garden Route Granite Fynbos

VT 46 Coastal Renosterbosveld (70%) (Acocks 1953). South Coast Renosterveld (22%) (Moll & Bossi 1983). LR 2 Afromontane Forest (67%) (Low & Rebelo 1996). BHU 100 Knysna Afromontane Forest (64%), BHU 28 Blanco Fynbos/Renosterveld Mosaic (36%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Garden Route—three main blocks south of the Outeniqua Mountains on the coastal plain from Botterberg west of Brandwaghoogte (south of Robinson Pass) to Groot Brak River; the largest block from Groot Brak River to Woodfield near the Wilderness (with a few strips along the coast from Bothastrand to the Wilderness); lastly, north of the lakes from Woodville to Hoogekraal Pass, west of Karatara. Altitude 0–300 m.

Vegetation & Landscape Features Moderately undulating plains and undulating hills on the coastal forelands. Dense proteoid and ericoid shrubby grassland. Proteoid and graminoid fynbos are dominant with ericaceous fynbos in seeps. In the west, most remnants of this type are dominated by proteas. Eastwards graminoid and ericaceous fynbos are dominant on the flat plateaus, with proteas confined to the steep slopes.

Geology & Soils George Batholith of the Cape Granite Suite. Deep, prismacutanic- and pedocutanic-dominated soils typical of Db land types (mainly).

Climate MAP 350–880 mm (mean: 600 mm), with a slight low in early winter. Mean daily maximum and minimum temperatures 27.8°C and 6.8°C for January–February and July, respectively. Frost incidence 2 or 3 days per year. See also climate diagram for FFg 5 Garden Route Granite Fynbos (Figure 4.92).

Important Taxa Tall Shrubs: *Passerina corymbosa* (d), *Cliffortia serpyllifolia*, *Protea coronata*, *P. lanceolata*, *P. neriifolia*. Low Shrubs: *Erica discolor* variant '*speciosa*' (d), *E. peltata* (d), *Phylica confusa* (d), *Syncarpha paniculata* (d), *Agathosma ovata*, *Anthospermum prostratum*, *Aspalathus asparagoides*, *Cliffortia falcata*, *Cullumia bisulca*, *Erica canaliculata*, *E. diaphana*, *E. formosa*, *Eriocephalus africanus*, *Hermannia angularis*, *Leucadendron salignum*, *Lobelia tomentosa*, *Metalasia pungens*, *Mimetes cucullatus*, *Pelargonium fruticosum*, *Relhania calycina*. Succulent Shrub: *Lampranthus sociorum*. Semiparasitic Shrubs: *Osyris compressa*, *Thesium virgatum*. Semiparasitic Epiphytic Shrub: *Viscum capense*. Geophytic Herb: *Schizaea pectinata*. Graminoids: *Tetraria cuspidata* (d), *Brachiaria serrata*, *Eragrostis capensis*, *Ficinia nigrescens*, *Heteropogon contortus*, *Pentaschistis eriostoma*, *Restio triticeus*, *Themeda triandra*.

Conservation Endangered. Target 23%. Only about 1% conserved in the proposed Garden Route National Park. About 70% has been transformed for cultivation (56%), pine plantations (7%) and by urban development (6%). Remnants are largely confined to isolated pockets on steeper slopes. Erosion moderate and high. Very few patches of this type remain in a pristine condition as most of it has been converted to pasture by liming, bush-cutting and frequent burning, and augmented with pasture grasses. Western remnants suggest that proteoid fynbos might have been dominant historically. It is easily converted to graminoid fynbos by regular fires and augmentation with pasture grasses.

References Drews (1980b), Hoare et al. (2000).

L. Mucina

Figure 4.96 FFg 5 Garden Route Granite Fynbos: Regenerating asteraceous fynbos on granite, with *Passerina glomerata*, *Phylica confusa*, *Syncarpha paniculata* and *Relhania calycina* on the southern Cape coast at Herolds Bay near George (Western Cape).

9.1.9 Limestone Fynbos

Limestone fynbos is a coherent edaphic unit floristically very different from the other fynbos vegetation. Even at detailed scales, limestone fynbos shares very few species with sandstone fynbos, and only a few with sand fynbos. Although intermediate communities do exist where neutral sand overlies limestone, the vegetation

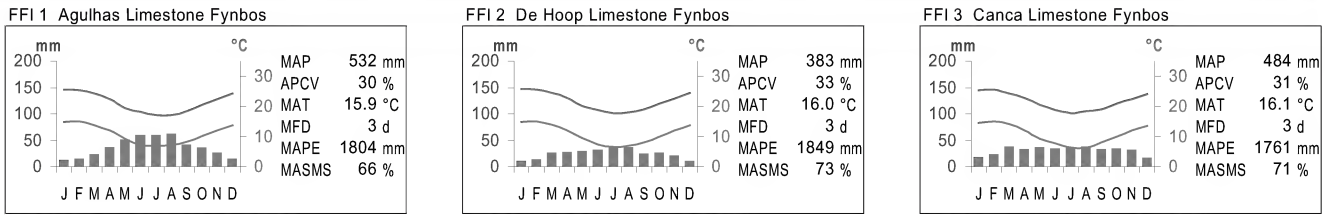


Figure 4.97 Climate diagrams of limestone fynbos units. Blue bars show the median monthly precipitation. The upper and lower red lines show the mean daily maximum and minimum temperature respectively. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days (days when screen temperature was below 0°C); MAPE: Mean Annual Potential Evaporation; MASMS: Mean Annual Soil Moisture Stress (% of days when evaporative demand was more than double the soil moisture supply).

boundaries are usually marked and in the order of less than a metre. Typically, however, the adjacent vegetation types are of similar structural types, even though they are floristically distinct. Many sister taxa exist across the boundaries—as exemplified by the Proteaceae genera *Protea* (*P. obtusifolia* on limestone, *P. susannae* on neutral sands, *P. compacta* on acid sands—all sister species), *Leucadendron* (*L. meridianum* on limestone, the unrelated *L. coniferum* or *L. galpinii* on neutral sands west and east of De Hoop Vlei, respectively, and *L. eucalyptifolium* or *L. xanthoconus* on acid sands), and *Leucospermum* (*L. truncatum* on limestone, *L. fulgens* and *L. praecox* on neutral sands—phylogenetically all sister species). Similar patterns exist in other plant families. Structurally, the limestone fynbos is dominated by asteraceous, restioid and proteoid fynbos. Graminoid and ericaceous fynbos structural types are largely absent. It has been proposed that limestone fynbos is a young unit, having evolved on sediments deposited during marine incursions in the Plio-Pleistocene and that endemic species must therefore be derived. During the period characterised by lower sea levels, the area of limestone would have been far larger—extending as far as 90 m below the current sea level and 200 km further south.

Limestone fynbos is restricted to the South Coast, with minor outliers at Cape Point and Macassar, reaching its greatest expanse from Agulhas to Mossel Bay. Similar limestone hills along the West Coast contain only strandveld communities—all markedly succulent and not able to support fire. Thus the high endemism and diversity of limestone on the South Coast have no analogue on the West Coast. However, the lack of deep acid sands means that sand fynbos is not nearly as extensive on the South Coast as on the West. The South Coast is characterised by more neutral sands. Succulent communities occur only on the littoral fringe along the South Coast, except where dune fields and raised platform topography retard the spread of fire.

Although limestone fynbos is a very distinct type, rich in endemic species and sharing very few species with other fynbos types, based on the distribution of endemic species, it can be divided into three natural units separated by gaps at Bredasdorp (a flat shale incursion) and Witsand (the Breede River flats).

The mapped extent of limestone and sand fynbos within the limestone fynbos area is not accurate. Only larger expanses of sand are mapped geologically, whereas even shallow (< 0.25 m deep) neutral sands are enough to displace limestone fynbos species completely and replace them with sand fynbos communities. While these communities are floristically distinct, some communities are structurally identical and cannot be distinguished on satellite images or aerial photographs. Therefore it is not possible to map the two types accurately at this stage. Small limestone lenses at Onrus, Hangklip, Macassar, Wolfgat and Cape Point were not mapped. Brief descriptions of these areas are found in Britton (1972), Taylor (1972b, 1983, 1984b), Low (1989) and Privett (1998). West of Hermanus, proper limestone communities do not seem to occur on the small outcrops present. Although these are spatially well defined, they do not appear to contain most of the characteristic limestone species, having depauperate, if distinct, sand fynbos communities.

Limestone fynbos contains all structural types of fynbos, determined primarily by slope and soil depth. Restioid fynbos and *Leucadendron muirii* proteoid fynbos occur on skeletal soils and limestone pavements. *Protea obtusifolia–Leucadendron meridianum* proteoid and scrub fynbos occur on deeper soils, with asteraceous fynbos on the drier northern slopes and ericaceous fynbos restricted to a few higher-altitude southern facies. The interface of sand and limestone fynbos often contains stands of Cape thicket, presumably relating to availability of water and fire protection where limestone outcrops form steeper slopes. Similarly, old sink holes (filled with a sand base) and shafts (leading to caves) are usually fringed with thicket elements, especially *Sideroxylon inerme*. Where rivers have deposited silt on the limestone, even in very thin layers, renosterveld elements become dominant. These are extremely localised and have not been mapped. A prime example of such 'limestone renosterveld' is found in De Hoop Nature Reserve (just south of the headquarters). Similarly, the areas of Bokkeveld shale that were covered by calcretes washed from the limestone have all been ploughed up (except for thicker expanses which are either limestone fynbos or, where protected from fire, have become thicket stands) and the nature of original vegetation types remains uncertain. These have been mapped as renosterveld.

FFI 1 Agulhas Limestone Fynbos

VT 47 Coastal Macchia (75%) (Acocks 1953). South Coast Strandveld (38%), Mesic Mountain Fynbos (27%) (Moll & Bossi 1983). LR 67 Limestone Fynbos (40%), LR 64 Mountain Fynbos (27%) (Low & Rebelo 1996). BHU 15 Hagelkraal Limestone Fynbos (44%), BHU 6 Agulhas Fynbos/Thicket Mosaic (25%), BHU 13 Springfield Sand Plain Fynbos (25%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Agulhas Plain from the vicinity of Hermanus to Bredasdorp and Struisbaai. The largest expanses of limestone are found between the Klein River Lagoon and Grootbos, around Hagelkraal, Heuningrug and Soetanysberg. Some unmapped outliers occur at Hangklip, Macassar (False Bay) and Buffels Bay (Cape Peninsula). The most southerly patch of the unit extends to within 300 m of the southern tip of Africa. Altitude 20–400 m, with some patches found at 500 m.

Vegetation & Landscape Features Low hills in plains, fragmented on the coastal margin of the Agulhas coastal forelands. Mainly on the plains, but with significant patches at higher altitudes such as on Soetanysberg. Moderately dense, low shrublands contain tall, emergent proteoids. Structurally it is

mainly asteraceous and proteoid fynbos, with restioid fynbos in sandy areas and on limestone pavements. Wetter areas, such as waterlogged bottomlands, are dominated by *Leucadendron linifolium* restioid fynbos, grading to FFd 7 Agulhas Sand Fynbos where sands become deeper.

Geology & Soils Shallow alkaline bedrock and alkaline, grey, regic sands on limestones of the Bredasdorp Formation. Land types mainly Hb, Db and Fa.

Climate MAP 410–660 mm (mean: 530 mm), peaking slightly from June to August. This is the wettest of all the limestone fynbos units. Mean daily maximum and minimum temperatures 25.5°C and 7.0°C for January and July, respectively. Frost incidence about 3 days per year. See also climate diagram for FFl 1 Agulhas Limestone Fynbos (Figure 4.97).

Important Taxa Tall Shrubs: *Chrysanthemoides monilifera*, *Protea obtusifolia*. Low Shrubs: *Leucadendron meridianum* (d), *L. muirii* (d), *Leucospermum truncatum* (d), *Adenandra obtusata*, *Aspalathus calcarea*, *A. pinguis* subsp. *australis*, *Erica propinqua*, *E. regia* subsp. *mariae*, *Euryops hebecarpus*, *Helichrysum dasyanthum*, *Indigofera brachystachya*, *Metalasia calcicola*, *Morella quercifolia*, *Passerina paleacea*, *Phylica ericoides*, *Wahlenbergia tenella*. Herb: *Ursinia tenuifolia* subsp. *ciliaris*. Geophytic Herb: *Freesia leichtlinii*. Graminoids: *Elegia microcarpa* (d), *Ficinia lateralis*, *F. truncata*, *Ischyrolepis leptoclados*, *Pentaschistis calcicola*, *P. pallida*, *Thamnochortus guthrieae*, *T. lucens*, *T. paniculatus*, *T. pluristachyus*.

Endemic Taxa Tall Shrubs: *Leucospermum patersonii* (d), *Erica magnisylvae*, *Mimetes saxatilis*. Low Shrubs: *Adenandra odoratissima*, *Agathosma abrupta*, *A. florulenta*, *A. paralia*, *A. sedifolia*, *Aspalathus aciloba*, *Diosma arenicola*, *D. awilana*, *D. demissa*, *D. guthriei*, *D. haelkraalensis*, *Erica aghillana*, *E. arenaria*, *E. calcareophila*, *E. excavata*, *E. glabella* subsp. *laevis*, *E. gracilipes*, *E. irregularis*, *E. occulta*, *E. pulvinata*, *E. saxicola*, *Felicia canaliculata*, *Indigofera hamulosa*, *Lobelia barkerae*, *Metalasia umbelliformis*, *Muraltia calycina*, *M. lewisiae*, *Osteospermum australe*, *Phylica selaginoides*, *Selago prostrata*, *Spatalla ericoides*. Succulent Shrubs: *Braunsia vanrensburgii*, *Delosperma mariae*, *Erepsia dunensis*. Herbs: *Centella gymnocarpa*, *Polygala dasyphylla*. Geophytic Herbs: *Cyrtanthus fergusoniae*, *Gladiolus miniatus*, *G. variegatus*, *Hesperantha juncifolia*. Succulent Herb: *Dorotheanthus ulularis*. Graminoids: *Hypodiscus procurrens*, *Thamnochortus fraternus*, *Tribolium ciliare*.

Conservation Least threatened. Target 32%. Statutorily conserved (8%) especially in the Agulhas National Park (small patches also in Kogelberg Biosphere Reserve, Table Mountain National Park and Wolfgat Nature Reserve), with a further 4% protected in private conservation areas such as Groot Hagelkraal and Oude Bosch. Only 5% has been transformed for cultivation and by urban development. Woody aliens *Acacia cyclops*, *A. saligna* and *Leptospermum laevigatum* are of conservation concern. Erosion very low and low.

Remark 1 Compared to the other two areas of limestone fynbos, this is the smallest but the most diverse. Given the lack of distinct structural types recorded in this vegetation, the floristic diversity is astounding.

Remark 2 In fire-safe habitats, such as depressions and on calcrete ridges, milkwood forests occur (Cowling et al. 1988, Von Maltitz et al. 2003).

References Boucher (1972, 1977, 1978, 1994b, 1995, 1997d), Kruger (1979), Cowling et al. (1988), Thwaites & Cowling (1988), Cowling (1990a, b), Heydenrych (1994), Richards (1994), Richards et al. (1995, 1997a, b), Willis & Cowling (1996), Willis et al. (1996), Mustart et al. (1997).

FFl 2 De Hoop Limestone Fynbos

VT 47 Coastal Macchia (95%) (Acocks 1953). Limestone Fynbos (91%) (Moll & Bossi 1983). LR 67 Limestone Fynbos (91%) (Low & Rebelo 1996). BHU 16 De Hoop Limestone Fynbos (87%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Broad swathe on the coastal forelands from Struisbaai and Bredasdorp to Infanta at the Breede River Mouth, remaining seawards of the Potberg and including the hills of Bobbejaanskrans and Voëlneskrans north of De Hoop Vlei. Altitude 20–240 m.

Vegetation & Landscape Features An inland range of hills, with plains and moderately undulating plains on the seaward foreland, in places dotted with karstic sinkholes and dry valleys (poljes). Some of the depressions can be longer than 2 km. Structurally it is mainly asteraceous and proteoid fynbos, with restioid fynbos in sandy areas. These areas were converted to grazing lawns in formerly disturbed (ploughed) areas currently with high game concentrations. Neutral to acid sands support FFd 7 Agulhas Sand Fynbos and FFd 9 Albertinia Sand Fynbos. Extensive skeletal calcrete over shale on the inland border may once also have held limestone fynbos or renosterveld ecotone communities, but these have all been converted to pasture and wheatland, and their vegetation was not documented before their conversion.

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Figure 4.98 FFl 1 Agulhas Limestone Fynbos: Shrubland with prominent orange-flowered *Leucospermum patersonii* (endemic to the vegetation unit), between Pearly Beach and Buffelsjags (Western Cape).

Geology & Soils Shallow, alkaline to neutral sand and bedrock, Glenrosa and Mispah forms on limestone of the Bredasdorp Formation. Topographically with less variegated relief than in the other limestone fynbos units, characterised by distinctive karstic valleys, sinkhole depressions and caves. Land types mainly Fc, Ib and Ic.

Climate MAP 250–530 mm (mean: 385 mm), peaking slightly in autumn and

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Figure 4.99 FFl 2 De Hoop Limestone Fynbos: Species-rich proteoid fynbos in De Hoop Nature Reserve (Overberg, Western Cape), with a prominent coastal limestone endemic *Leucadendron muirii* (left) and a local endemic *Metalasia calcicola* (Asteraceae).

Remark 1 Curiously, the boundary between two sand fynbos units (FFd 7 Agulhas Sand Fynbos and FFd 9 Albertinia Sand Fynbos) is De Hoop Vlei—not the Bredasdorp Gap as in the case of limestone fynbos units.

Remark 2 Fire-safe habitats such as steep krantzes support dense sclerophyllous thickets and small *Sideroxylon inerme* forest patches. Fire-safe sinkhole depressions have *Sideroxylon inerme* stands and occasionally dune thicket. These are sometimes converted to grazing lawns of creeping grass (mainly dominated by *Cynodon dactylon*) in areas of high antelope populations (bontebok, eland, rheebok) and zebras.

References Van der Merwe (1977a), Uys (1983), Heydenrych (1994), Willis & Cowling (1996), Willis et al. (1996), C. Boucher (unpublished data), L. Mucina (unpublished data).

winter with a low from December to February. This is the driest of the limestone fynbos types. Mean daily maximum and minimum temperatures 25.6°C and 6.6°C for January–February and July, respectively. Frost incidence about 3 days per year. See also climate diagram for FFl 2 De Hoop Limestone Fynbos (Figure 4.97).

Important Taxa Low Shrubs: *Leucadendron meridianum* (d), *L. muirii* (d), *Leucospermum truncatum* (d), *Metalasia calcicola* (d), *Passerina galpinii* (d), *Acmadenia densifolia*, *Adenandra obtusata*, *Agathosma serpyllacea*, *Aspalathus calcarea*, *A. incurvifolia*, *Asparagus capensis* var. *capensis*, *Erica propinqua*, *E. regia* subsp. *mariae*, *E. spectabilis*, *Euryops ericoides*, *E. hebecarpus*, *Metalasia erectifolia*, *Oedera squarrosa*, *Syncarpha canescens*, *Ursinia dentata*. Tall Shrubs: *Chrysanthemoides monilifera* (d), *Euryops linearis* (d), *Protea obtusifolia* (d), *P. lanceolata*. Herbs: *Cotula turbinata* (d), *Ursinia tenuifolia* subsp. *ciliaris*. Geophytic Herbs: *Cyanella lutea* (d), *Freesia leichtlinii*, *Haemanthus coccineus*, *Lachenalia muirii*, *Ledebouria ovalifolia*, *Neopatersonia uitenhagensis*, *Polyxena ensifolia*, *Strumaria squarrosa*. Graminoids: *Cynodon dactylon* (d), *Ficinia truncata* (d), *Thamnochortus paniculatus* (d), *Elegia microcarpa*, *Ficinia praemorsa*, *Ischyrolepis leptoclados*, *Pentaschistis calcicola*, *Thamnochortus erectus*, *T. guthrieae*, *T. lucens*, *T. pluristachyus*.

Endemic Taxa Low Shrubs: *Acmadenia mundiana*, *Argyrolobium harmsianum*, *Aspalathus pallescens*, *A. prostrata*, *Brachysiphon mundii*, *Cliffortia burgersii*, *Erica scytophylla*, *E. sperata*, *E. uysii*, *Euchaetis intonsa*, *Felicia ebracteata*, *Lobostemon daltonii*, *Pteronia diosmifolia*, *Sutera titanophila*. Herb: *Galium bredasdorpense*.

Conservation Least threatened. Target 32%. Statutorily conserved in De Hoop Nature Reserve (27%), with an additional 1% enjoying protection in the Andrewsfield Private Nature Reserve. Only 2% has been transformed (cultivation). Alien *Acacia cyclops* is dense in places. Erosion very low.

FFl 3 Canca Limestone Fynbos

VT 47 Coastal Macchia (91%) (Acocks 1953). Limestone Fynbos (63%) (Moll & Bossi 1983). LR 67 Limestone Fynbos (63%) (Low & Rebelo 1996). BHU 17 Canca Limestone Fynbos (56%) (Cowling et al. 1999b, Cowling & Heijnis 2001). STEP Stillbay Dune Thicket (26%) (Vlok & Euston-Brown 2002).

Distribution Western Cape Province: Coastal forelands from Witsand at the mouth of the Breede River to Mossel Bay, with narrow outliers close to the coast between Hartenbos and Groot Brak River. Furthest occurrence inland is at about 10 km south of Riversdale or roughly 25 km from the coast. Altitude 20–300 m.

Vegetation & Landscape Features A series of hills with parallel crests, sand-filled plains and undulating hills. Neutral and acid sands support FFd 9 Albertinia Sand Fynbos, which dominates the valleys and is far more extensive than in the other limestone fynbos units. This landscape is dominated by the Canca se Leegte and Wankoe depressions, with most of the limestone fynbos on the hill tops and ridges. This vegetation

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Figure 4.100 FFl 3 Canca Limestone Fynbos: Proteoid fynbos with *Protea obtusifolia* (foreground) and *Leucadendron meridianum* (background), on limestone ridges north of Still Bay (Western Cape).

has tall, emergent proteoids in a medium dense low shrubland—mainly asteraceous and proteoid fynbos, with restioid fynbos on skeletal soils. Communities east of the Gouritz River lack the proteoid overstorey and are poorer in species, with *Erica* particularly rare. Rutaceae are dominant and succulents and geophytes are more abundant, grading into succulent thicket on the coast. Local diversity east of the Gouritz River depends on the extent of limestone patches, with smaller outcrops lacking characteristic species.

Geology & Soils Shallow alkaline to neutral grey regic sands and Glenrosa and Mispah forms on limestone of the Bredasdorp Formation. Land types mainly Fc and Hb.

Climate MAP 310–630 mm (mean: 485 mm), relatively constant throughout the year, but with a low from December to February. Mean daily maximum and minimum temperatures 25.5°C and 6.3°C for February and July, respectively. A mild temperature regime, with frost incidence only about 3 days per year. This is a marginally warmer unit than the other two limestone fynbos units. See also climate diagram for FFl 3 Canca Limestone Fynbos (Figure 4.97).

Important Taxa ([T]Cape thickets) Tall Shrubs: *Protea obtusifolia* (d), *Chrysanthemoides monilifera*, *Erica prolata*, *Protea lanceolata*. Low Shrubs: *Erica spectabilis* (d), *Leucadendron meridianum* (d), *L. muirii* (d), *Acmadenia densifolia*, *A. obtusata*, *Agathosma muirii*, *Aspalathus alopecurus*, *A. calcarea*, *A. incurvifolia*, *A. sanguinea* subsp. *sanguinea*, *Chascanum cernuum*, *Diospyros dichrophylla*[T], *Erica regia* subsp. *mariae*, *E. vestita*, *Euryops ericoides*, *Indigofera zeyheri*, *Metalasia calcicola*, *Phylica pubescens* var. *orientalis*. Herb: *Osteospermum scariosum*. Geophytic Herb: *Freesia leichtlinii*. Graminoids: *Ischyrolepis leptoclados* (d), *Ceratocaryum argenteum*, *Elegia microcarpa*, *Ficinia truncata*, *Pentaschistis calcicola*, *Thamnochortus erectus*, *T. lucens*, *T. pluristachyus*.

Endemic Taxa Low Shrubs: *Aspalathus candidula*, *Athanasia cochlearifolia*, *Erica baueri* subsp. *gouriquae*, *E. platycalyx*, *Euryops muirii*, *Hermannia muirii*, *Lobostemon belliformis*, *Metalasia luteola*, *Muraltia barkerae*, *M. depressa*, *Oedera steyniae*. Succulent Shrubs: *Delosperma virens*, *Ruschia leptocalyx*. Herb: *Sutera placida*. Geophytic Herb: *Tritonia squalida*. Succulent Herb: *Haworthia mirabilis* var. *paradoxa*.

Conservation Least threatened. Target 32%. Only very small portion statutorily conserved in the Pauline Bohnen and Geelkrans Nature Reserves, with an additional 3% protected in private reserves such as Rein's Coastal (Gouriqua), Stilbaai Fynbos, Die Duine, Mosselbankfontein and Annet. Some 14% has already been transformed, mainly for cultivation. Aliens *Acacia cyclops* and *A. saligna* are common. Erosion is very low.

Remarks Fire-safe habitats such as depressions and limestone ridges support Cape Milkwood Forests (see Von Maltitz et al. 2003), often with notably darker soils and extending well into the sandy soils. *Protea lanceolata* is a marked dominant in wetter areas and in ecotones, with dune thicket patches away from the coast. West of Blombos a small transitional form between *Leucospermum praecox* and *L. truncatum* is as much at home in the limestone as in the sand fynbos. There are still remnants of the shallow calcretes over shale north of the limestone deposits (not mapped). These do bear limestone fynbos, but more often have thicket communities, but this may be due to conversion of the veld into pasture and wheatlands, with only thicker calcretes remaining and protected from fire.

References Muir (1929), Rebelo et al. (1991), Heydenrych (1994), Boucher & Rode (1995a, b), Willis & Cowling (1996), Willis et al. (1996), Boucher (1998c).

9.2 Renosterveld

Renosterveld vegetation occupies 29% of the area of the Fynbos Biome and 25% of the area of the CFR. By far most renosterveld vegetation units (86%) occur on shale, but it can be found on any substrate except sandstone and quartzite (on which it may be found locally where there are overlying remnants of shale or colluvial clay layers).

9.2.1 Shale Renosterveld

Shale renosterveld is the predominant renosterveld group, accounting for 86% of the area of renosterveld. Renosterveld, unlike fynbos, extends beyond the Fynbos Biome on the Cape Fold Belt onto the karoo shales, where rainfall patterns allow a high grass cover (chiefly *Merxmuellera stricta*) and abundance of nonsucculent shrubs such as *Elytropappus rhinocerotis*. Affinities are more with neighbouring karoo types than with other renosterveld types, which show strong affinities to their neighbouring fynbos types, especially regarding geophytes. Within the classical Fynbos Biome, shale renosterveld accounts for 90% of the area of renosterveld.

Low & Rebelo (1996) mapped an extensive patch of renosterveld in the Spektakelberg Pass area on the Escarpment west of Springbok in northern Namaqualand. Surrounded by the unique and endemic-rich SKn 2 Namaqualand Shale Shrubland, some renosterbos-dominated shrublands do occur here on the exposed edge of the Escarpment (see Van Jaarsveld & Koutnik 2004, p. 54), probably linked to more frequent fog precipitation and possibly also orographic rain in the region. Low & Rebelo's coverage (see above) is too extensive and comprises much of the succulent shrubland on shale as well. Due to lack of adequate field data, we have mapped this area as part of SKn 2 Namaqualand Shale Shrubland pending better data.

FRs 1 Vanrhynsdorp Shale Renosterveld

VT 69 Macchia (56%), VT 28 Western Mountain Karoo (32%), VT 31 Succulent Karoo (12%) (Acocks 1953). Dry Mountain Fynbos (58%), Mesic Mountain Fynbos (32%) (Moll & Bossi 1983). LR 64 Mountain Fynbos (92%) (Low & Rebelo 1996). BHU 45 Bokkeveld Mountain Fynbos Complex (75%), BHU 46 Gifberg Mountain Fynbos Complex (16%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Northern and Western Cape Provinces: Below generally west- and north-facing sandstone cliffs of the Bokkeveld Escarpment and Matsikamma Mountains from Die Toring north of Van Rhyns Pass to the Gifberge near Klawer. Also extensive in internal valleys of the Koebee in the area of the confluence of the Oorlogs River and the Klein Kobee River. Altitude 150–880 m.

Vegetation & Landscape Features Valley bottoms and steep slopes below often sheer sandstone cliffs, supporting moderately tall, cupressoid-leaved shrublands dominated by renosterbos. Geophytes and annuals are common and conspicuous in spring. In some areas, transitional to Succulent Karoo shrublands, extensive *Montinia caryophyllacea* stands occur (see SKs 13 Klawer Sandy Shrubland).

Geology & Soils Clays and clayey loams primarily derived from mudstone and siltstone of the Knersvlakte Subgroup (Vanrhynsdorp Group) and schist and phyllite of the older Gariep Supergroup (last two are of Namibian Erathem). Soils are primarily of Glenrosa and Mispah form, closely associated with quartzite and shale of Nardouw Subgroup (Table Mountain Group) forming neighbouring cliffs and screes. Land types mainly Fa and Ib.

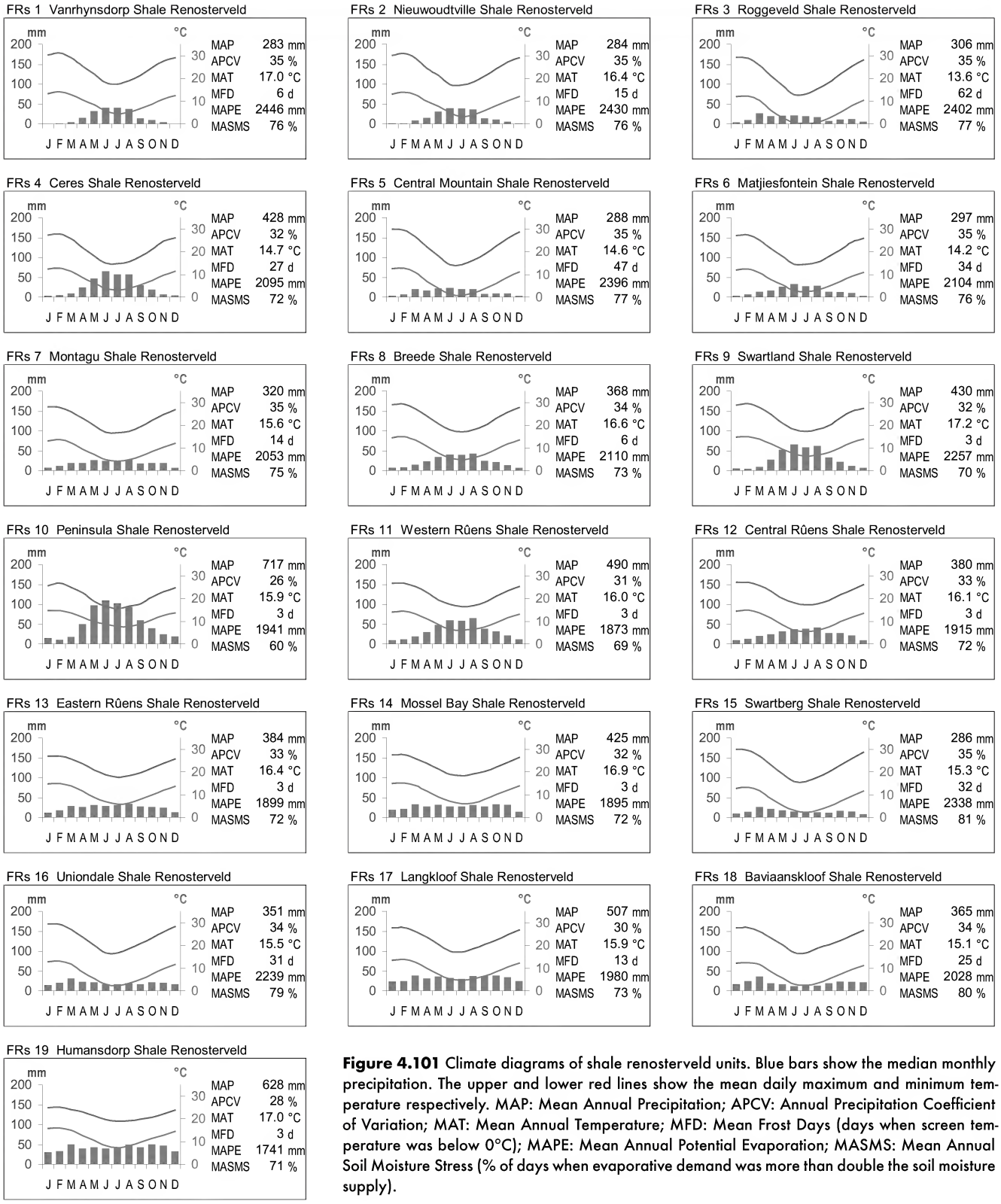

Figure 4.101 Climate diagrams of shale renosterveld units. Blue bars show the median monthly precipitation. The upper and lower red lines show the mean daily maximum and minimum temperature respectively. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days (days when screen temperature was below 0°C); MAPE: Mean Annual Potential Evaporation; MASMS: Mean Annual Soil Moisture Stress (% of days when evaporative demand was more than double the soil moisture supply).

Climate MAP 180–450 mm (mean: 285 mm), peaking from May to August. Mean daily maximum and minimum temperatures 31.2°C and 4.4°C for February and July, respectively. Frost incidence 3–10 days per year. See also climate diagram for FRs 1 Vanrhynsdorp Shale Renosterveld (Figure 4.101).

Important Taxa Tall Shrubs: *Dodonaea viscosa* var. *angustifolia* (d), *Montinia caryophyllacea* (d), *Nylandtia scoparia* (d), *Rhus incisa* (d), *Diospyros austro-africana*, *D. glabra*[T], *Halleria lucida*[T], *Maytenus acuminata*, *Olea europaea* subsp. *africana*, *Wiborgia sericea*. Low Shrubs: *Berkheya fruticosa* (d), *Elytropappus rhinocerotis* (d), *Helichrysum revolutum* (d), *Passerina truncata* subsp. *truncata* (d), *Pteronia pallens* (d), *Amphiglossa tomentosa*, *Anthospermum spathulatum* subsp. *spathulatum*, *Asparagus capensis* var. *capensis*, *Eriocephalus africanus* var. *africanus*, *E. microphyllus* var. *pubescens*, *Felicia dubia*, *Galenia africana*, *Helichrysum cylindriflorum*, *Maytenus oleoides*, *Pelargonium praemorsum*, *Pharnaceum dichotomum*, *Pteronia paniculata*, *Struthiola leptantha*. Succulent Shrubs: *Didelta spinosa* (d), *Euphorbia burmannii* (d), *E. loricata*, *E. mauritanica*, *Othonna*

coronopifolia, *Tylecodon paniculatus*, *T. wallichii* subsp. *wallichii*. Woody Climber: *Secamone alpini*. Herbs: *Cotula bipinnata*, *Dimorphotheca pluvialis*, *Gorteria diffusa* subsp. *diffusa*, *Nemesia anisocarpa*, *Osteospermum pinnatum*, *Plantago cafra*, *Rhynchopsidium pumilum*, *Ursinia cakilefolia*. Geophytic Herb: *Oxalis purpurea*. Succulent Herbs: *Tetragonia hirsuta*, *T. robusta* var. *psiloptera*. Herbaceous Climber: *Cyphia angustifolia*. Graminoids: *Ehrharta thunbergii* (d), *Stipa capensis* (d), *Ehrharta barbinodis*, *E. longiflora*, *E. ramosa* subsp. *aphylla*, *Pentaschistis patula*, *Schismus barbatus*, *Tribolium echinatum*.

Endemic Taxon Geophytic Herb: *Eriospermum minutipustulatum*.

Conservation Least threatened. Target 27%. Statutorily conserved (4%) in the Oorlogskloof Nature Reserve. About 2% transformed (cultivation). Erosion very low and moderate.

L. Mucina

Figure 4.102 FRs 2 Nieuwoudtville Shale Renosterveld: Shale outcrops with traces of Permian glacial activity (striae) surrounded by shrublands (*Elytropappus, Eriocephalus, Hermannia*) and herblands dominated by annual and geophytic spring flora (*Felicia, Geissorhiza, Lapeirousia, Lachenalia, Leysera, Ursinia* etc.) south of Nieuwoudtville (Bokkeveld, Northern Cape).

Remarks This unit is distinct from FRs 2 Nieuwoudtville Shale Renosterveld primarily by the lack of endemic geophytes characteristic of the latter, but also by abundant succulents found in this vegetation at the lower transitions towards the Succulent Karoo shrublands. Vanrhynsdorp Shale Renosterveld and FFs 1 Bokkeveld Sandstone Fynbos share a number of regional endemics, such as *Athanasia leptocephala* and *Podalyria pearsonii*. Fynbos and Cape thicket communities occur on the scree and talus cones at the base of the sandstone cliffs, but these have not been mapped.

References Van Jaarsveld (1982), N. Helme (unpublished data).

FRs 2 Nieuwoudtville Shale Renosterveld

VT 28 Western Mountain Karoo (83%) (Acocks 1953). Mosaic of Dry Mountain Fynbos & Karroid Shrublands (93%) (Moll & Bossi 1983). LR 56 Upland Succulent Karoo (91%) (Low & Rebelo 1996). BHU 35 Nieuwoudtville Inland Renosterveld (57%), BHU 75 Western Mountain Vygieveld (34%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Northern Cape Province: Bokkeveld Plateau at Nieuwoudtville extending in a 1–4 km wide strip 13 km south of Boererus on the Oorlogskloof River near Papkuilsfontein and almost 20 km north of Nieuwoudtville in the vicinity of Kleinplaas. Altitude 600–850 m.

Vegetation & Landscape Features Flat tableland covered with uniformly structured low renosterveld shrubland with small, woody shrubs (0.5–1.6 m tall) and a variable grass layer. A diverse geophyte and annual community is prevalent in the wet season. Dominants are strongly related to soil, displaying large compositional turnover with soil texture, depth and aspect. The transition to fynbos in the west is abrupt and determined by sandstone geology. Progressively increasing aridity results in a more gradual transition to SKt 2 Hantam Karoo in the east.

Geology & Soils The soils have a well-developed clay E-horizon (leading to seasonal water-logging of soils) in places and are derived from Dwyka Group diamictites (tillites) that have a fine-grained (shale) matrix. There are even areas with only skeletal clays over the Nardouw Subgroup rocks (Cape Supergroup). Land types mainly Db and Fb.

Climate MAP 190–350 mm (mean: 285 mm), peaking from May to August. Mean daily maximum and minimum temperatures 31.0°C and 3.2°C for February and July, respectively. Frost incidence about 10 days per year. See also climate diagram for FRs 2 Nieuwoudtville Shale Renosterveld (Figure 4.101).

Important Taxa Low Shrubs: *Elytropappus rhinocerotis* (d), *Eriocephalus purpureus* (d), *Asparagus capensis* var. *capensis*, *Pentzia incana*, *Wiborgia tetraptera*. Herbs: *Arctotheca calendula* (d), *Cotula nudicaulis* (d), *Leysera tenella* (d), *Nemesia cheiranthus* (d), *Senecio cakilefolius* (d). *S. erosus*. Geophytic Herbs: *Hesperantha cucullata*, *Moraea bifida*, *Ornithogalum conicum* subsp. *strictum*. Graminoids: *Merxmuellera stricta* (d), *Chaetobromus involucratus* subsp. *dregeanus*, *Ehrharta calycina*.

Endemic Taxa Low Shrubs: *Euryops mirus*, *Hermannia johanssenii*, *Selago chalarantha*. Geophytic Herbs: *Babiana pauciflora*, *Bulbinella eburniflora*, *Corycium ingeanum*, *Eriospermum erinum*, *E. glaciale*, *Geissorhiza splendidissima*, *Lachenalia alba*, *Moraea aspera*, *M. pseudospicata*, *Romulea discifera*, *R. sabulosa*, *Sparaxis tricolor*, *Strumaria picta*.

Conservation Endangered. Target 27%. None conserved in statutory or private conservation areas. Almost 50% transformed, mainly for cultivation. While most of the area of this vegetation unit has been transformed into croplands, the remaining portions are threatened by fire, overgrazing and by infestation by aliens such as *Medicago polymorpha*. This unit is a major node of geophytic diversity requiring a higher conservation status. Erosion moderate and high.

Remarks Together with FRd 1 Nieuwoudtville-Roggeveld Dolerite Renosterveld, this region represents the highest known concentration of geophytes, with bulbous species constituting 40% of the flora. Of interest are the number of sister taxa, with one species in this unit and the other in the neighbouring FRd 1 Nieuwoudtville-Roggeveld Dolerite Renosterveld.

References Snijman & Perry (1987), Manning & Goldblatt (1997b), S.A. Todd & J. Donaldson (unpublished data).

FRs 3 Roggeveld Shale Renosterveld

VT 43 Mountain Renosterbosveld (65%), VT 28 Western Mountain Karoo (33%) (Acocks 1953). LR 60 Escarpment Mountain Renosterveld (52%), LR 56 Upland Succulent Karoo (43%) (Low & Rebelo 1996).

Distribution Northern and Western Cape Provinces: Major part of the Roggeveld bordered by the edge of the western Great Escarpment mostly above the Tanqua Basin. South of the Hantam Plateau region in the upper parts of the range of the Keiskieberge and isolated high plateaus to the south including plateaus such as Grootberg, Saalfontein se Berg, Sneewkrans and Swaarweerberg encompassing the vicinity of Middelpos and Sutherland, reaching as far east as the higher-lying areas of the Teekloof Pass south of Fraserburg along the northwest summit plateaus of the Nuweveldberge. Altitude 1 200–1 900 m.

Vegetation & Landscape Features Undulating, slightly sloping plateau landscape, with low hills and broad shallow valleys, supporting mainly moderately tall shrublands dominated by renosterbos, with a rich geophytic flora in the wetter and rocky habitats.

Geology & Soils Mudrocks and sandstones of the Adelaide Subgroup (Beaufort Group of the Karoo Supergroup) dominate the geology. Some intrusions of the Karoo Dolerite Suite are also present. Glenrosa and Mispah forms are prominent. Land types mainly Fc and Da.

Climate MAP 180–430 mm (mean: 305 mm), even throughout the year, showing a slight peak in March. Mean daily maximum and minimum temperatures 29.3°C and 0.2°C for January and July, respectively. Frost incidence is remarkably high for a renosterveld type (30–70 days per year). See also climate diagram for FRs 3 Roggeveld Shale Renosterveld (Figure 4.101).

Important Taxa Tall Shrub: *Euryops lateriflorus*. Low Shrubs: *Asparagus capensis* var. *capensis*, *Chrysocoma oblongifolia, Dimorphotheca cuneata*, *Diospyros austro-africana*, *Elytropappus rhinocerotis*, *Eriocephalus africanus* var. *africanus*, *E. ericoides* subsp. *ericoides*, *E. eximius*, *Euryops cuneatus*, *E. imbricatus*, *E. marlothii*, *E. microphyllus*, *E. trifidus*, *Felicia filifolia* subsp. *filifolia*, *F. muricata* subsp. *cinerascens*, *F. scabrida*, *Helichrysum hamulosum*, *H. lucilioides*, *Hermannia multiflora*, *Lessertia fruticosa*, *Nenax microphylla*, *Passerina nivicola*, *Pteronia erythrochaeta*, *Rosenia oppositifolia*, *Selago articulata*, *S. saxatilis*, *Ursinia pilifera*, *Zygophyllum spinosum*. Succulent Shrub: *Stomatium rouxii*. Herbs: *Cotula microglossa*, *Diascia parviflora*, *Lasiopogon muscoides*, *Pharnaceum croceum*, *Senecio hastatus*. Geophytic Herbs: *Drimia intricata*, *Geissorhiza heterostyla*, *Hesperantha cucullata*, *Oxalis obtusa*, *Romulea atrandra*, *R. diversiformis*, *R. rosea*, *R. tetragona*, *R. tortuosa*, *Spiloxene capensis*. Succulent Herb: *Crassula corallina* subsp. *corallina*. Herbaceous Succulent Climber: *Crassula roggeveldii*. Graminoids: *Ehrharta calycina*, *Pentaschistis aristifolia*, *P. patula*, *Schismus inermis*, *S. scaberrimus*.

Biogeographically Important Taxa (both Roggeveld-Hantam endemics) Herb: *Zaluzianskya violacea*. Geophytic Herb: *Androcymbium hantamense*.

Endemic Taxa Low Shrub: *Euryops sulcatus*. Herbs: *Lasiospermum poterioides*, *Manulea diandra*. Geophytic Herbs: *Daubenya aurea*, *Gladiolus marlothii*, *Ixia thomasiae*, *Polyxena longituba*, *Romulea hallii*, *R. komsbergensis*, *R. multifida*, *R. subfistulosa*, *R. syringodeoflora*.

Conservation Least threatened. Target 27%. None conserved in statutory or private conservation areas. Only 1% transformed, but danger of overgrazing is locally high. Erosion mainly moderate, with the remainder low.

Remarks The Roggeveld is named after the indigenous rye species (*Secale africana*) now almost extinct due to grazing pressure. The Roggeveld region is rich in endemic geophytes, most notably the monotypic *Devia xeromorpha*. It is an important centre of radiation for several other genera such as *Hesperantha* and *Romulea* (Iridaceae), *Zaluzianskya* (Scrophulariaceae) as well as *Lachenalia* and *Polyxena* (both Hyacinthaceae). Most of the endemics of this vegetation type are found on the dolerite cappings. This unit belongs to the core of the Hantam-Roggeveld Centre of Endemism (Van Wyk & Smith 2001).

Reference Van Wyk & Smith (2001).

FRs 4 Ceres Shale Renosterveld

VT 69 Macchia (62%), VT 46 Coastal Renosterbosveld (35%) (Acocks 1953). Central Mountain Renosterveld (20%) (Moll & Bossi 1983). LR 61 Central Mountain Renosterveld (88%) (Low & Rebelo 1996). BHU 37 Waveren-Bokkeveld Inland Renosterveld (54%), BHU 36 Kouebokkeveld Inland Renosterveld (28%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

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Figure 4.103 FRs 3 Roggeveld Shale Renosterveld: Renosterbos (*Elytropappus rhinocerotis*) shrubland on the top of Verlatenkloof near Sutherland (Northern Cape).

Distribution Western Cape Province: Warm Bokkeveld Valley at Ceres and Laastedrift to the east; Cederberg from Matjiesrivier (not mapped) to Koue Bokkeveld at Blinkberg Pass, the Odessa area north of Gydoberg and Baviaanshoek. Altitude 500–1 300 m.

Vegetation & Landscape Features Moderately undulating plains and lower mountain slopes supporting medium tall cupressoid-leaved shrubland dominated by renosterbos. Heuweltjies are prominent in places.

Geology & Soils Clays derived from shale and sandstone of the Ceres (mostly) and the Bidouw Subgroups of the Bokkeveld Group. Some Nardouw Subgroup shales (Table Mountain Group) and Dwyka diamictites (Karoo Supergroup) also

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Figure 4.104 FRs 4 Ceres Shale Renosterveld: Renosterbos (*Elytropappus rhinocerotis*) dominating shrublands of the Warm Bokkeveld on the Swaarmoed Pass, southeast of Ceres (Western Cape).

occur. Glenrosa and Mispah forms are prominent. Land types mainly Fb, Fa and Bb.

Climate MAP 290–720 mm (mean: 430 mm), peaking from May to August. The Warm Bokkeveld communities are much more arid than those in the Koue Bokkeveld. Mean daily maximum and minimum temperatures 27.9°C and 3.2°C for February and July, respectively. Frost incidence 10–40 days per year. See also climate diagram for FRs 4 Ceres Shale Renosterveld (Figure 4.101).

Important Taxa Low Shrubs: *Agathosma squamosa*, *Aspalathus desertorum*, *Elytropappus rhinocerotis*, *Galenia africana*, *Pteronia incana*, *Stoebe plumosa*. Herbs: *Helichrysum crispum*, *Lotononis longicephala*. Geophytic Herbs: *Geissorhiza heterostyla*, *G. ornithogaloides* subsp. *marlothii*, *G. pappei*, *Lachenalia ameliae*, *Romulea flava*, *R. tetragona*, *R. tortuosa*, *Wurmbea variabilis*. Succulent Herb: *Crassula muscosa*.

Endemic Taxa Succulent Shrub: *Didymaotus lapidiformis*. Herb: *Lotononis exstipulata*.

Conservation Vulnerable. Target 27%. Few patches conserved in the Ben Etive Nature Reserve, an additional 1% in the Koue Bokkeveld (mountain catchment area) and the Matroosberg Private Nature Reserve. Some 36% of the area transformed, mainly by cultivation; also threatened by short-interval burning and overgrazing. Erosion varies widely, from very low to high.

Remarks This unit possibly also occurs in the FFb 1 Northern Inland Shale Band Vegetation at lower altitudes from Pakhuis Pass southwards, and also locally within SKv 3 Agter-Sederberg Shrubland, where it occurs at the upper reaches in wetter areas from Matjiesrivier to Blinkberg—these occurrences were too localised or too poorly surveyed to be mapped.

References Taylor (1996), C. Boucher (unpublished data).

FRs 5 Central Mountain Shale Renosterveld

VT 43 Mountain Renosterbosveld (85%) (Acocks 1953). LR 60 Escarpment Mountain Renosterveld (94%) (Low & Rebelo 1996). BHU 40 Roggeveld Inland Renosterveld (59%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Northern and Western Cape Provinces: Southern and southeastern slopes of the Klein-Roggeveldberge and Komsberg below the Roggeveld section of the Great Escarpment (facing the Moordenaars Karoo) as well as farther east below Besemgoedberg and Suurkop west of Merweville and in the west in the Karookop area between Losper se Berg and high points around Thyshoogte. Altitude 1 050–1 500 m.

Vegetation & Landscape Features Slopes and broad ridges of low mountains and escarpments, with tall shrubland dominated by renosterbos and large suites of mainly non-succulent karoo shrubs and with a rich geophytic flora in the undergrowth or in more open, wetter or rocky habitats.

Geology & Soils Clayey soils overlying Adelaide Subgroup (Beaufort Group of the Karoo Supergroup) mudstones and subordinate sandstones. Glenrosa and Mispah forms are prominent. Land types mainly Ib and Fc.

Climate Arid to semi-arid climate. MAP 180–410 mm (mean: 290 mm), with relatively even rainfall, but still showing a slight high in autumn-winter. Mean daily maximum and minimum temperatures 29.9°C and 0.9°C for January and July, respectively. Frost incidence 20–50 days per year. See also climate diagram for FRs 5 Central Mountain Shale Renosterveld (Figure 4.101).

Important Taxa Low Shrubs: *Elytropappus rhinocerotis* (d), *Amphiglossa tomentosa*, *Asparagus capensis* var. *capensis*, *Chrysocoma ciliata*, *C. oblongifolia*, *Diospyros austro-africana*, *Eriocephalus africanus* var. *africanus*, *E. ericoides* subsp. *eri-*

M.C. Rutherford

Figure 4.105 FRs 5 Central Mountain Shale Renosterveld: Renosterbos (*Elytropappus rhinocerotis*) shrubland with numerous geophytes including white *Bulbinella elegans* and *Oxalis obtusa* in the Klein Roggeveld north of Matjiesfontein (Western Cape).

coides, *E. eximius*, *E. grandiflorus*, *E. microphyllus* var. *pubescens*, *E. pauperrimus*, *E. purpureus*, *Euryops imbricatus*, *Exomis microphylla*, *Felicia filifolia* subsp. *filifolia*, *F. muricata* subsp. *muricata*, *F. ovata*, *Galenia africana*, *Helichrysum dregeanum*, *H. lucilioides*, *Hermannia multiflora*, *Lessertia fruticosa*, *Lycium cinereum*, *Nenax microphylla*, *Pelargonium abrotanifolium*, *Pentzia incana*, *Pteronia ambrariifolia*, *P. glauca*, *P. glomerata*, *P. incana*, *P. sordida*, *Rosenia glandulosa*, *R. humilis*, *R. oppositifolia*, *Selago albida*, *Tripteris sinuata*, *Zygophyllum spinosum*. Succulent Shrubs: *Delosperma subincanum*, *Drosanthemum lique*, *Euphorbia stolonifera*, *Trichodiadema barbatum*, *Tylecodon reticulatus* subsp. *reticulatus*, *T. wallichii* subsp. *wallichii*. Woody Climber: *Asparagus aethiopicus*. Herbs: *Dianthus caespitosus* subsp. *caespitosus*, *Heliophila pendula*, *Lepidium desertorum*, *Osteospermum acanthospermum*, *Senecio hastatus*. Geophytic Herbs: *Bulbine asphodeloides*, *Drimia intricata*, *Othonna auriculifolia*, *Oxalis obtusa*. Succulent Herbs: *Crassula deceptor*, *C. muscosa*, *C. tomentosa* var. *glabrifolia*, *Senecio radicans*. Graminoids: *Ehrharta calycina*, *Karroochloa purpurea*, *Merxmuellera stricta*.

Conservation Least threatened. Target 27%. None conserved in statutory or private conservation areas. Only about 1% transformed. Erosion moderate.

Remark This is a very poorly known renosterveld type despite its interesting biogeographical borderline position—the unit straddles the Fynbos, Succulent Karoo and marginally the Nama-Karoo Biomes. It does not appear to have any endemic species.

Reference Acocks (1988).

FRs 6 Matjiesfontein Shale Renosterveld

VT 43 Mountain Renosterbosveld (38%), VT 70 False Macchia (25%) (Acocks 1953). Karroid Shrublands (51%), Central Mountain Renosterveld (44%) (Moll & Bossi 1983). Inland Renoster Shrubland (Campbell 1985). LR 61 Central Mountain Renosterveld (46%), LR 58 Little Succulent Karoo (40%) (Low & Rebelo 1996). BHU 81 Touws Vygieveld (34%), BHU 39 Matjies Inland Renosterveld (21%) (Cowling et al. 1999b, Cowling & Heijnis 2001). Witteberg Renosterveld (Vlok 2002).

Distribution Western Cape Province: From De Doorns and the top of the Theronsberg Pass in the west to Gamka Poort in the east, remaining north of the Waboomberg and Warmwaterberg in the Little Karoo and north of the Anysberg and Groot Swartberg and positioned south of the Tanqua Karoo, the Grootrivier near Matjiesfontein and the Floriskraal Dam south-east of Laingsburg. This type surrounds the many higher elevation ridges of FFq 3 Matjiesfontein Quartzite Fynbos and FFh 2 Matjiesfontein Shale Fynbos. Altitude 750–1 300 m.

Vegetation & Landscape Features Low mountains, parallel hills and mid-altitude plateaus supporting a low, open to medium dense, leptophyllous shrubland with a medium dense matrix of short, divaricate shrubs, dominated by renosterbos. Heuweltjies present at low densities in places.

Geology & Soils Clays and loams derived from Witteberg and Bokkeveld Group shales of the Cape Supergroup; Glenrosa and Mispah forms prominent. Land types mainly Fc, Ic, Ib and Fb.

Climate MAP 150–470 mm (mean: 300 mm), peaking slightly from May to August. Mean daily maximum and minimum temperatures 27.4°C and 2.4°C for February and July, respectively. Frost incidence 10–40 days per year. See also climate diagram for FRs 6 Matjiesfontein Shale Renosterveld (Figure 4.101).

Important Taxa Low Shrubs: *Elytropappus rhinocerotis* (d), *Aspalathus alpestris*, *Asparagus capensis* var. *capensis*, *Athanasia flexuosa*, *Chrysocoma ciliata*, *C. oblongifolia*,

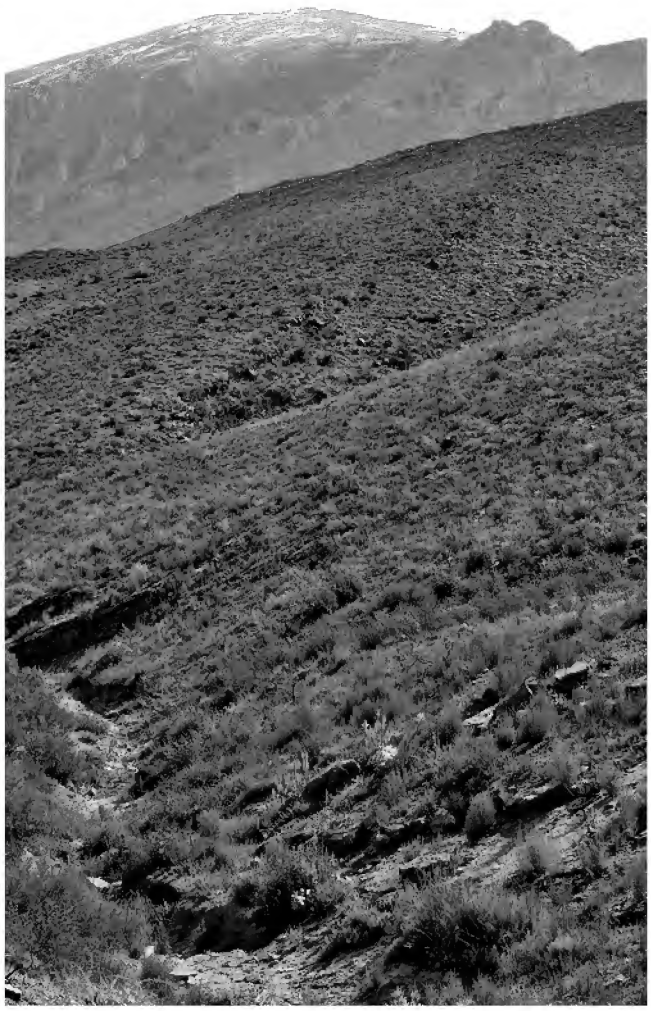

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Figure 4.106 FRs 6 Matjiesfontein Shale Renosterveld: Post-fire regeneration of renosterveld shrubland on the Hex River Pass, with flora rich in dwarf shrubs (*Hermannia*, *Indigofera*), annuals and geophytes (*Cotula macroglossa*, *Kniphofia sarmentosa*). The snow-clad summit of Matroosberg (2 249 m) is in the background.

Eriocephalus ericoides subsp. *ericoides*, *Euryops cuneatus*, *E. imbricatus*, *E. microphyllus*, *Helichrysum simulans*, *Oedera genistifolia*, *Passerina truncata* subsp. *truncata*, *Pteronia sordida*. Succulent Shrub: *Antimima dasyphylla*. Herbs: *Cotula macroglossa*, *Foveolina dichotoma*, *Lepidium desertorum*, *Rhynchopsidium sessiliflorum*, *Rumex lanceolatus*, *Ursinia nana*. Geophytic Herbs: *Chlorophytum lewisiae*, *Gethyllis campanulata*, *Romulea atrandra*, *R. sphaerocarpa*, *R. tortuosa*, *Trachyandra thyrsoidea*. Succulent Herb: *Crassula lanceolata* subsp. *lanceolata*. Graminoids: *Bromus pectinatus*, *Ehrharta calycina*, *E. capensis*, *E. delicatula*, *Hyparrhenia hirta*, *Hypodiscus sulcatus*, *Pentaschistis rigidissima*.

Endemic Taxa Low Shrub: *Lotononis comptonii*. Geophytic Herbs: *Disa cochlearis*, *Hesperantha truncatula*, *Romulea malaniae*.

Conservation Least threatened. Target 27%. About 7% in total conserved in the Anysberg Nature Reserve (CapeNature) and private conservation areas such as Rooikrans. Some 9% totally transformed (mainly cultivation). Erosion moderate to very low as well as very high in places.

Remarks This is a very poorly studied vegetation unit. Although grouped with FRs 5 Central Mountain Shale Renosterveld by Acocks (1988), this unit has more fynbos and fewer karoo elements. This unit also occurs in the FFb 3 Central Inland Shale

Band Vegetation at moderate altitudes (1 300 m), but has not been mapped as its extent is uncertain.

References Acocks (1988), Vlok (2002).

FRs 7 Montagu Shale Renosterveld

VT 26 Karroid Broken Veld (44%), VT 43 Mountain Renosterbosveld (32%) (Acocks 1953). Central Mountain Renosterveld (64%), Karroid Shrublands (21%) (Moll & Bossi 1983). LR 61 Central Mountain Renosterveld (71%), LR 58 Little Succulent Karoo (21%) (Low & Rebelo 1996). BHU 41 Montagu Inland Renosterveld (54%) (Cowling et al. 1999b, Cowling & Heijnis 2001). Montagu Renosterveld, Touwsfontein Renosterveld (Vlok 2002).

Distribution Western Cape Province: Patches in the western Little Karoo south of the Waboomberg and Warmwaterberg and south of the Anysberg and Klein Swartberg as well as along the northern foothills of the Langeberg and the southern foothills of the Anysberg, Klein Swartberg, Rooiberg and Gamkaberg, from The Koo in the west to Calitzdorp and Cloete's Pass in the east. The largest patch occurs between Montagu and Barrydale. Altitude 200–1 020 m.

Vegetation & Landscape Features Undulating hilly landscape with broad valleys supporting open, tall shrubland in a medium dense matrix of short, divaricate shrubs, dominated by renosterbos. Transitions with Succulent Karoo units can be observed at lower altitudes.

Geology & Soils Clays mostly derived from Bokkeveld and some Witteberg Group shales; Glenrosa and Mispah forms prominent. Some extensive quartzitic pebble fields occur. Land types mainly Fc and Fb.

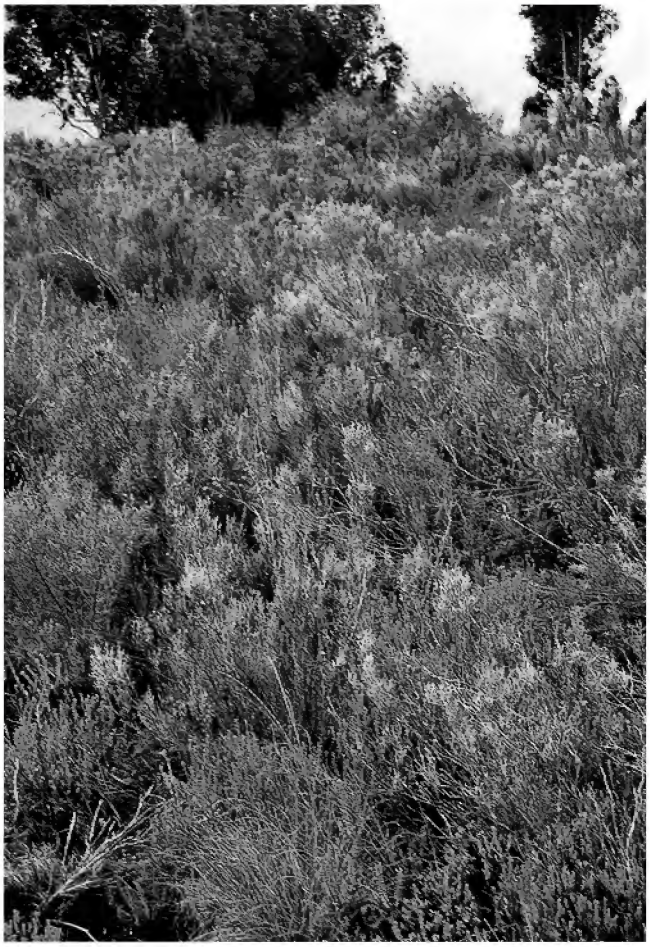

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Figure 4.107 FRs 7 Montagu Shale Renosterveld: Renosterbos (*Elytropappus rhinocerotis*) shrubland in the Koo near Montagu, Western Little Karoo (Western Cape).

Climate MAP 140–560 mm (mean: 320 mm), with a slight peak in winter. Mean daily maximum and minimum temperatures 28.1°C and 4.1°C for January and July, respectively. Frost incidence 10–20 days per year. See also climate diagram for FRs 7 Montagu Shale Renosterveld (Figure 4.101).

Important Taxa Small Tree: *Acacia karroo*. Succulent Tree: *Aloe ferox*. Tall Shrubs: *Diospyros pallens*, *Dodonaea viscosa* var. *angustifolia*, *Euclea undulata*, *Metalasia densa*, *Rhus pterota*. Low Shrubs: *Athanasia vestita* (d), *Chrysocoma oblongifolia* (d), *Elytropappus rhinocerotis* (d), *Felicia filifolia* subsp. *filifolia* (d), *Oedera genistifolia* (d), *O. squarrosa* (d), *Pteronia pallens* (d), *Tripteris sinuata* (d), *Artemisia afra*, *Athanasia microcephala*, *Chrysocoma ciliata*, *Cymbopappus adenosolen*, *Diospyros austro-africana*, *Gnidia inconspicua*, *G. sericea*, *Helichrysum hamulosum*, *Hermannia flammea*, *Leucadendron salignum*, *Lycium cinereum*, *Passerina comosa*, *P. obtusifolia*, *Pteronia incana*, *Selago corymbosa*. Succulent Shrubs: *Aloe arborescens*, *Crassula ciliata*. Herbs: *Arctotheca calendula*, *Cotula turbinata*, *Helichrysum crispum*. Geophytic Herb: *Romulea sphaerocarpa*. Graminoids: *Merxmuellera stricta* (d), *Cynodon dactylon*.

Biogeographically Important Taxon Geophytic Herb: *Ixia gloriosa* (Little Karoo endemic).

Endemic Taxa Low Shrubs: *Anginon tenuior*, *Argyrolobium crinitum*, *Diosma strumosa*, *Macledium relhanioides*. Succulent Shrubs: *Antimima biformis*, *Drosanthemum albiflorum*, *Tylecodon albiflorus*. Geophytic Herbs: *Ixia superba*, *Syringodea saxatilis*, *Tritonia watermeyeri*.

Conservation Least threatened. Target 27%. Statutorily conserved in the Anysberg Nature Reserve (2%), and an additional 4% protected in private reserves such as Botterboom, Kanaland and Doornkloof. Some 15% transformed (cultivation). Local low levels of infestation with alien *Acacia cyclops* and *A. saligna*. Erosion mainly high, but also very low in some areas.

Remark This vegetation type is in urgent need of research attention.

References Muir (1929), Vlok (2002).

FRs 8 Breede Shale Renosterveld

VT 26 Karroid Broken Veld (45%), VT 69 Macchia (33%) (Acocks 1953). Central Mountain Renosterveld (39%), Karroid Shrublands (17%) (Moll & Bossi 1983). LR 61 Central Mountain Renosterveld (70%), LR 58 Little Succulent Karoo (23%) (Low & Rebelo 1996). BHU 38 Ashton Inland Renosterveld (56%), BHU 87 Robertson Broken Veld (23%), BHU 37 Waveren-Bokkeveld Inland Renosterveld (14%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Patches in the Breede River Valley from Tulbagh to Swellendam; more specifically, most of the valley floor between Tulbagh and Wolseley, isolated small patches to the vicinity of Worcester, diverse patches between Stettyn and McGregor south of the Breede River, a near continuous but irregular band on the southern foothills of the Langeberg from Philipsdale near Worcester to Ashton. The most extensive area occurs near Ashton. McGregor and the confluence of the Riviersonderend and Breede Rivers west of Swellendam. Altitude 100–650 m.

Vegetation & Landscape Features Low hills, slightly undulating to undulating plains and lower mountain slopes. In the western regions low, cupressoid-leaved shrubland (with scattered emergent small trees) is dominated by renosterbos. Elements

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Figure 4.108 FRs 8 Breede Shale Renosterveld: Renosterveld shrublands with rich geophyte flora (*Lachenalia, Cyphia bulbosa, Spiloxene capensis* etc.) near Tulbagh Station, south of Tulbagh (Western Cape).

of shale fynbos are present. In the eastern regions open, tall shrublands (possibly closely affiliated to FRs 12 Central Rûens Shale Renosterveld) are found, with microphyllous shrubs forming the dominant layer. Breede Shale Renosterveld grades into SKv 7 Robertson Karoo in the central valley, with karoo shrublands usually occurring on the northern aspects and renosterveld found on the southern aspects, with a decline in the extent of the karoo shrublands to the south. Heuweltjies are very prominent, with either bush clumps in moister areas or succulent shrubs in drier habitats.

Geology & Soils Clays and loams mostly derived from Bokkeveld and some Witteberg Group shales as well as Porterville Formation phyllite shale of the Malmesbury Group (Namibian Erathem) in the northwest. Glenrosa and Mispah forms are dominant. Land types mainly Fb, Fa and Ic.

Climate MAP 210–610 mm (mean: 370 mm), peaking from May to August. Mean daily maximum and minimum temperatures 29.3°C and 4.8°C for February and July, respectively. Frost incidence 3–8 days per year. See also climate diagram for FRs 8 Breede Shale Renosterveld (Figure 4.101).

Important Taxa Tall Shrubs: *Euclea undulata* (d), *Lycium ferocissimum* (d), *Dodonaea viscosa* var. *angustifolia*, *Euryops tenuissimus*, *Rhus angustifolia*, *R. undulata*. Low Shrubs: *Aspalathus steudeliana* (d), *Elytropappus rhinocerotis* (d), *Galenia africana* (d), *G. herniariaefolia* (d), *G. secunda* (d), *Oedera sedifolia* (d), *O. squarrosa* (d), *Pentzia incana* (d), *Pteronia incana* (d), *P. paniculata* (d), *Anthospermum aethiopicum*, *Aspalathus candicans*, *A. pachyloba* subsp. *macroclada*, *A. submissa*, *A. varians*, *Carissa bispinosa* subsp. *bispinosa*, *Chrysocoma ciliata*, *C. coma-aurea*, *Felicia filifolia* subsp. *filifolia*, *F. flanaganii*, *Freylinia undulata*, *Hermannia vestita*, *Heterolepis peduncularis*, *Metalasia octoflora*, *Oedera genistifolia*, *Passerina obtusifolia*, *Pteronia fasciculata*, *Selago fruticosa*, *Senecio pinifolius*, *Wahlenbergia tenella*. Succulent Shrubs: *Delosperma pageanum* (d), *Euphorbia burmannii* (d), *E. mauritanica* (d), *Ruschia caroli* (d), *R. festiva* (d), *Tylecodon paniculatus* (d), *Adromischus filicaulis* subsp. *filicaulis*, *Aloe microstigma* subsp. *microstigma*, *Crassula atropurpurea* var. *atropurpurea*, *C. pubescens* subsp. *pubescens*, *C. rupestris*, *C. tetragona*, *Pelargonium alternans*, *Psilocaulon coriarium*, *Ruschia multiflora*, *Tetragonia fruticosa*, *T. sarcophylla*, *Tylecodon grandiflorus*. Herb: *Hypericum lalandii*. Geophytic Herbs: *Babiana melanops*, *Freesia caryophyllacea*, *Geissorhiza heterostyla*, *G. inflexa*, *G. ornithogaloides* subsp. *ornithogaloides*, *G. purpureolutea*, *G. tulbaghensis*, *Lachenalia polyphylla*, *Ornithogalum dubium*, *Oxalis goniorrhiza*, *Wurmbea monopetala*. Succulent Herbs: *Crassula aphylla*, *C. muscosa*. Graminoids: *Ehrharta calycina*, *E. villosa* var. *villosa*, *Ficinia ramosissima*, *Hyparrhenia hirta*, *Ischyrolepis gaudichaudiana*, *Merxmuellera stricta*.

Endemic Taxa Low Shrubs: *Aspalathus macrocarpa*, *Cliffortia varians*, *Lotononis rigida*. Succulent Shrubs: *Acrodon purpureostylus*, *Drosanthemum aureopurpureum*, *D. hallii*, *Lampranthus hurlingii*. Geophytic Herbs: *Babiana villosa*, *Freesia fucata*, *Ixia vanzijliae*, *I. vinacea*, *Moraea incurva*, *M. radians*.

Conservation Vulnerable. Target 27%. The unit is statutorily conserved in the Vrolijkheid Nature Reserve (2%) as well as in Langeberg-wes and Matroosberg mountain catchment areas. Some 31% transformed, mainly by cultivation. Alien *Pinus pinaster* and several species of *Acacia* occur locally, at low levels. Erosion spans high and very low.

Remarks Little known and in urgent need of detailed study before totally modified by agriculture and mining. Around Noree (between Robertson and Worcester) there are small exposed dolomite lenses (partly subject to mining), supporting species such as *Aloe microstigma*, *Antimima leipoldtii* and a new species of *Gazania* pending formal description. The identity of this vegetation and its possible recognition as a separate vegetation unit needs further study. This unit extends onto FFb 4 Central Coastal Shale Band Vegetation in the Langeberg near Nuy but as the extent of this is unknown it has not been mapped.

References Olivier (1966), Joubert (1968), Norton (1977), Van der Merwe (1977b), Boucher & Moll (1981), Chesselet (1985), Boschoff (1989), Smitheman & Perry (1990), Wood (1990).

FRs 9 Swartland Shale Renosterveld

VT 46 Coastal Renosterbosveld (85%) (Acocks 1953). LR 62 West Coast Renosterveld (86%) (Low & Rebelo 1996). BHU 31 Swartland Coast Renosterveld (63%), BHU 32 Boland Coast Renosterveld (27%) (Cowling et al. 1999b, Cowling & Heijnis 2001). Coast Renoster Shrubland (Campbell 1985).

Distribution Western Cape Province: Large, generally continuous areas of the Swartland and the Boland on the West Coast lowlands, from Het Kruis in the north, southwards between the Piketberg and Olifantsrivierberge, widening appreciably in the region around Moorreesburg between Gouda and Hopefield, and encompassing Riebeek-Kasteel, Klipheuwel, Philadelphia, Durbanville, Stellenbosch to the south and Sir Lowry's Pass Village near Gordon's Bay. Altitude 50–350 m.

Vegetation & Landscape Features Moderately undulating plains and valleys supporting low to moderately tall leptophyllous shrubland of varying canopy cover as well as low, open shrubland dominated by renosterbos. Heuweltjies are a very prominent local feature of the environment, forming 'hummockveld' near Piketberg and giving the Tygerberg Hills their name. Stunted trees and thicket are often associated with the

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Figure 4.109 FRs 9 Swartland Shale Renosterveld: Renosterbos (*Elytropappus rhinocerotis*) shrublands on Malmesbury shales at the foot of Spitskop, near Piketberg, with *Moraea tulbaghensis* (orange, Red Data species), *Lampranthus dilutus* (mauve-flowered vygie) and *Ixia lutea* (cream-coloured in the background).

heuweltjies. Disturbed areas are dominated by *Athanasia trifurcata* and *Otholobium hirtum*. Patches of *Cynodon dactylon* 'grazing lawns' also occur in abundance.

Geology & Soils Clay soils derived from Malmesbury Group shales (specifically the Porterville Formation in the north and east and the Moorreesburg Formation in the west). The soils contain prismacutanic and pedocutanic diagnostic horizons and Glenrosa and Mispah forms are predominant. Land types mainly Db, Fb and Da.

Climate Winter-rainfall regime, with MAP 270–670 mm (mean: 430 mm), peaking from May to August. Mean daily maximum and minimum temperatures 29.6°C and 6.3°C for February and July, respectively. Frost incidence 3 or 4 days per year. Mists are common in winter. See also climate diagram for FRs 9 Swartland Shale Renosterveld (Figure 4.101).

Important Taxa ([W]Wetlands) Tall Shrubs: *Aspalathus acuminata* subsp. *acuminata* (d), *Olea europaea* subsp. *africana* (d), *Rhus angustifolia* (d), *R. incisa* (d), *Chrysanthemoides monilifera*, *Euryops speciosissimus*, *E. tenuissimus*, *Gymnosporia buxifolia*, *Lebeckia cytisoides*. Low Shrubs: *Anthospermum aethiopicum* (d), *A. spathulatum* subsp. *tulbaghense* (d), *Elytropappus rhinocerotis* (d), *Eriocephalus africanus* var. *africanus* (d), *Euryops thunbergii* (d), *Galenia secunda* (d), *Helichrysum cymosum* (d), *H. teretifolium* (d), *Osteospermum spinosum* (d), *Otholobium hirtum* (d), *Agathosma glandulosa*, *Aspalathus aculeata*, *A. pinguis* subsp. *pinguis*, *A. spinosa* subsp. *flavispina*, *A. tridentata* subsp. *stauranthra*, *A. varians*, *Asparagus rubicundus*, *Athanasia trifurcata*, *Cliffortia marginata*, *Diosma hirsuta*, *Euclea acutifolia*, *Felicia filifolia* subsp. *filifolia*, *F. hyssopifolia*, *Galenia africana*, *Lebeckia cinerea*, *Leucadendron lanigerum* var. *lanigerum*, *Marasmodes polycephala*, *Metalasia dregeana*, *M. octoflora*, *Muraltia decipiens*, *M. ononidifolia*, *Oftia africana*, *Passerina truncata* subsp. *truncata*, *Phylica gracilis*, *Plecostachys serpyllifolia*, *Pteronia divaricata*, *P. incana*, *Rhus dissecta*, *Senecio pubigerus*, *Stoebe plumosa*. Succulent Shrubs: *Euphorbia burmannii* (d), *E. mauritanica*, *Lampranthus elegans*. Woody Climber: *Microloma sagittatum*. Herbs: *Berkheya armata* (d), *B. rigida*, *Cotula turbinata*, *Echiostachys spicatus*, *Lichtensteinia obscura*, *Manulea cephalotes*, *Senecio laxus*, *Stachys aethiopica*. Geophytic Herbs: *Cyanella hyacinthoides* (d), *Melasphaerula ramosa* (d), *Albuca maxima*, *Aristea africana*, *Babiana melanops*, *Cheilanthes capensis*, *Disa physodes*, *Geissorhiza imbricata* subsp. *bicolor*[W], *G. inflexa*, *G. juncea*, *G. purpureolutea*, *G. tulbaghensis*, *Lachenalia longibracteata*, *L. pallida*, *L. polyphylla*, *Mohria caffrorum*, *Ornithogalum thyrsoides*, *Oxalis pes-caprae*, *Romulea flava*, *R. leipoldtii*, *R. rosea*, *R. tabularis*, *Watsonia marginata*. Graminoids: *Cynodon dactylon* (d), *Ehrharta calycina* (d), *Elegia capensis* (d), *E. recta* (d), *E. tectorum* (d), *Ficinia brevifolia* (d), *Ischyrolepis capensis* (d), *Merxmuellera stricta* (d), *Ehrharta delicatula*, *E. thunbergii*, *Hordeum capense*, *Merxmuellera arundinacea*, *Tribolium hispidum*.

Endemic Taxa Low Shrubs: *Leucadendron verticillatum* (d), *Aspalathus acanthophylla*, *A. horizontalis*, *A. pinguis* subsp. *longissima*, *A. pinguis* subsp. *occidentalis*, *A. puberula*, *A. rectistyla*, *Cliffortia acockii*, *Lotononis complanata*, *Serruria incrassata*. Succulent Shrubs: *Erepsia ramosa*, *Ruschia patens*, *R. pauciflora*. Herb: *Indigofera triquetra*. Geophytic Herbs: *Aristea lugens*, *Babiana angustifolia*, *B. odorata*, *B. secunda*, *Hesperantha pallescens*, *H. spicata* subsp. *fistulosa*, *Lachenalia liliflora*, *L. mediana* var. *rogersii*, *L. orthopetala*, *Lapeirousia fastigiata*, *Moraea gigandra*, *M. tulbaghensis*, *Oxalis fragilis*, *O. involuta*, *O. leptocalyx*, *O. levis*, *O. macra*, *O. perineson*, *O. strigosa*, *Pelargonium viciifolium*.

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Figure 4.110 FRs 9 Swartland Shale Renosterveld: A typical landscape mosaic of the West Coast renosterveld region—arable fields surround renosterveld shrublands which become limited to solitary hills (below Piekenierskloof Pass, Western Cape).

Conservation This is a critically endangered vegetation unit. Target 26%, but since 90% of the area has been totally transformed (mainly for cropland), the target remains unattainable. The remnants are found in isolated pockets, usually on steeper ground. So far only a few patches have been included in conservation schemes (e.g. Elandsberg, Paardenberg). Aliens include *Acacia saligna* (very scattered over 65%), *A. mearnsii* (very scattered over 62%) as well as several species of *Prosopis* and *Eucalyptus*. Alien annual grasses of the genera *Avena*, *Briza*, *Bromus*, *Lolium*, *Phalaris* and *Vulpia* are a primary problem in remnant patches. Other serious aliens include herbs such as *Erodium cicutarium*, *E. moschatum*, *Echium plantagineum* and *Petrorhagia prolifera*. Erosion very low and low.

Remark 1 No floristic or phytosociological support for the north-south split into Swartland and Boland BHUs (Cowling & Heijnis 2001) could be found. Nor could we find any patterns associated with the coastal-inland geological belts (Tygerberg, Moorreesburg and Brandwacht Formations).

Remark 2 Various special vegetation units are embedded within the West Coast renosterveld matrix, composed of vernal pools, ferricrete gravels, quartz patches and seasonally wet lowlands—all ranking among the most threatened Cape habitats and housing many endemic taxa.

References Linder (1976), Boucher (1977, 1978, 1980, 1983, 1987, 1989a), Boucher & Moll (1981), Paterson (1982), Jones (1986), Lötter & Van Wageningen (1988), Landman & Nel (1989), Duvenhage (1993), Von Hase et al. (2003), Walton (2006), N. Helme (unpublished data).

FRs 10 Peninsula Shale Renosterveld

VT 69 Macchia (57%), VT 34 Strandveld of West Coast (40%) (Acocks 1953). West Coast Renosterveld (7%) (Moll & Bossi 1983). LR 62 West Coast Renosterveld (63%), LR 68 Sand Plain Fynbos (32%) (Low & Rebelo 1996). BHU 55 Cape Peninsula Mountain Fynbos Complex (71%), BHU 12 Blackheath Sand Plain Fynbos (29%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Signal Hill and on the lower northern slopes of Table Mountain and Devil's Peak; approximately centred on the city bowl of Cape Town. Altitude 0–350 m.

Vegetation & Landscape Features Gentle to steep lower slopes with tall, open shrubland and grassland, typically with renosterbos not appearing very prominent. This vegetation is very grassy due to frequent fires and lack of grazing. On Devil's Peak these 'renosterveld grasslands' are frequently mowed for grazing. On south-facing slopes and upper slopes this unit merges into fynbos. The early seral stages are dominated by *Asparagus capensis*, *Hyparrhenia hirta*, *Haemanthus sanguineus*, various *Oxalis* species and resprouting *Rhus lucida*, after which tussock grasses, shrubs and ferns emerge. After only 12 months the reseeding species start to become more obvious.

Geology & Soils Clay soils derived from shale of the Tygerberg Formation, Malmesbury Group; Glenrosa, Mispah and Lamotte forms prominent. Land types mainly Fa and Ga.

Climate MAP 480–870 mm (mean: 720 mm), peaking markedly from May to August. This is the wettest renosterveld type by far. Mean daily maximum and minimum temperatures 26.7°C and 7.8°C for February and July, respectively. Frost incidence 2 or 3 days per year. See also climate diagram for FRs 10 Peninsula Shale Renosterveld (Figure 4.101).

Important Taxa ([T]Cape thickets) Tall Shrubs: *Gymnosporia buxifolia*[T] (d), *Noltea africana* (d), *Rhus angustifolia*[T] (d), *R. glauca*[T] (d), *R. lucida*[T] (d), *R. tomentosa*[T] (d), *Myrsine africana*[T], *Olea europaea* subsp. *africana*[T], *Putterlickia pyracantha*[T], *Rhus laevigata*[T]. Low Shrubs: *Cliffortia polygonifolia* (d), *Elytropappus rhinocerotis* (d), *Eriocephalus africanus* var. *africanus* (d), *Helichrysum cymosum* (d), *H. patulum* (d), *Lobostemon argenteus* (d), *Salvia africana-caerulea* (d), *Stoebe cinerea* (d), *Anthospermum spathulatum* subsp. *spathulatum*, *Chrysanthemoides incana*, *Clutia pulchella*, *Diosma hirsuta*, *Erica baccans*, *Gnidia inconspicua*, *Otholobium hirtum*, *Salvia africana-lutea*. Succulent Shrubs: *Erepsia anceps*, *Tylecodon grandiflorus*. Herbs: *Stachys aethiopica* (d), *Knowltonia capensis*, *Pseudoselago serrata*. Geophytic Herbs: *Cheilanthes capensis* (d), *Mohria caffrorum* (d), *Asplenium aethiopicum*, *Geissorhiza inflexa*, *G. pusilla*. Graminoids: *Hyparrhenia hirta* (d), *Cymbopogon marginatus*, *Ehrharta erecta*, *Eragrostis curvula*, *Merxmuellera stricta*, *Pentaschistis aspera*, *Themeda triandra*, *Tribolium uniolae*.

Conservation Critically endangered vegetation unit. Target of 26% is unattainable since 77% of the area has been totally transformed (urban sprawl, cultivation and building of road infrastructure). It is statutorily conserved in the Table Mountain National Park (19%). A fair proportion of the conserved area on Devil's Peak is covered by pine and gum parkland. These should be restored to renosterveld as soon as possible. Notable aliens include various species of *Acacia* (especially *A. melanoxylon*). Erosion very low.

Remarks This vegetation burns every 3–5 years to the consternation of Cape Town citizens. Large portions of Signal Hill have been, however, protected from fire for up to 25 years. The upper reaches of this mapped unit on the northern slopes of Devil's Peak should be FFh 5 Cape Winelands Shale Fynbos.

References Adamson (1927), Boucher & Moll (1981), Joubert (1991), Joubert & Moll (1992), Britton & Jackelman (1995, 1996), Cowling et al. (1996b), Simmons (1996).

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Figure 4.111 FRs 10 Peninsula Shale Renosterveld: Shrubland on Signal Hill, Cape Town, showing *Elytropappus rhinocerotis, Rhus lucida, Lobostemon fruticosus, Anthospermum spathulatum, Cliffortia polygonifolia* and *Helichrysum patulum*.

FRs 11 Western Rûens Shale Renosterveld

VT 46 Coastal Renosterbosveld (79%), VT 69 Macchia (21%) (Acocks 1953). LR 63 South and South-west Coast Renosterveld (94%) (Low & Rebelo 1996). BHU 33 Overberg Coast Renosterveld (92%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Western parts of the Rûens region (Overberg)—from Bot River and Villiersdorp eastwards, surrounding the Caledon Swartberg, and approximately to a line between Napier and Genadendal. Altitude 60–450 m.

Vegetation & Landscape Features Moderately undulating plains, today mostly stripped of natural vegetation and where preserved, supporting an open to medium dense, cupressoid and small-leaved, low to moderately tall grassy shrubland dominated by renosterbos. Heuweltjies are not conspicuous. This unit is distinguished from other Rûens renosterveld types by the absence of *Hermannia flammea* and rare occurrence of *Aloe ferox* and *Acacia karroo* complex. Shrubby Asteraceae increase as grazing reduces the palatable grass component (mostly *Hyparrhenia hirta*), resulting in subsequent erosion.

Geology & Soils Clays and loams derived from Bokkeveld Group shales, particularly the Ceres Subgroup. Glenrosa and Mispah forms are dominant. Land types mainly Fb and Fa.

Climate MAP 360–700 mm (mean: 490 mm), with a peak in winter (May to August). Mean daily maximum and minimum temperatures 26.9°C and 6.1°C for February and July, respectively. Frost incidence about 3 days per year. See also climate diagram for FRs 11 Western Rûens Shale Renosterveld (Figure 4.101).

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Figure 4.112 FRs 11 Western Rûens Shale Renosterveld: *Watsonia alectroides* (Asphodelaceae) in a remnant of a shale renosterveld along the road between Bredasdorp and Caledon (Western Cape).

Important Taxa Tall Shrub: *Rhus pallens* (d). Low Shrubs: *Aspalathus nigra* (d), *A. spinosa* subsp. *flavispina* (d), *A. submissa* (d), *Asparagus capensis* var. *capensis* (d), *Athanasia trifurcata* (d), *Elytropappus rhinocerotis* (d), *Erica setacea* (d), *Felicia filifolia* subsp. *filifolia* (d), *Helichrysum petiolare* (d), *Metalasia acuta* (d), *Oedera squarrosa* (d), *Printzia polifolia* (d), *Stoebe plumosa* (d), *Aspalathus steudeliana*. Succulent Shrub: *Drosanthemum flavum*. Herb: *Corymbium cymosum* (d). Geophytic Herbs: *Bobartia indica* (d), *Micranthus junceus* (d), *Geissorhiza ornithogaloides* subsp. *ornithogaloides*, *Oxalis duriuscula*, *O. livida* var. *altior*. Graminoids: *Cymbopogon pospischilii* (d), *Cynodon dactylon* (d), *Ehrharta calycina* (d), *Ficinia nigrescens* (d), *Hyparrhenia hirta* (d), *Ischyrolepis capensis* (d), *Merxmuellera stricta* (d), *Themeda triandra* (d).

Endemic Taxa Tall Shrub: *Freylinia helmei*. Low Shrubs: *Agathosma* sp. nov. *(N. Helme 2530* BOL), *Cullumia selago*. Succulent Shrubs: *Drosanthemum insolitum*, *Erepsia villiersii*. Herbs: *Felicia nigrescens*, *Peucedanum pungens*. Geophytic Herbs: *Ixia stricta*, *Moraea barnardiella*, *M. comptonii*, *M. debilis*, *Sparaxis fragrans*, *S. maculosa*.

Conservation Critically endangered. Target 27%. None of the area is conserved statutorily and only a small portion (about 1%) enjoys protection in the Witdraai Private Nature Reserve. Some 86% has already been transformed (thus target is unattainable), mostly by cultivation. Only the steepest slopes carry remnants of the natural vegetation. Erosion very low and low.

References Boucher & Moll (1981), Cowling et al. (1988), Boucher (1999d), Von Hase et al. (2003), N. Helme (unpublished data).

FRs 12 Central Rûens Shale Renosterveld

VT 46 Coastal Renosterbosveld (88%) (Acocks 1953). South Coast Renosterveld (2%) (Moll & Bossi 1983). LR 63 South and South-west Coast Renosterveld (96%) (Low & Rebelo 1996). BHU 33 Overberg Coast Renosterveld (90%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Central parts of the Rûens region (Overberg) from Greyton and Stormsvlei (and Bromberg) to Napier and Bredasdorp and centred on Klipdale and Protem; also on the coastal flats southeast of Bredasdorp towards Arniston. Fragmented outliers are found on the southern part of the Agulhas Plain between Soetendalsvlei and Waskraalsvlei. Altitude 20–340 m.

Vegetation & Landscape Features Moderately undulating plains and pans. Vegetation is open to medium dense cupressoid and small-leaved, low to moderately tall grassy shrubland, usually dominated by renosterbos. It is distinguished from the Eastern Rûens Shale Renosterveld by the absence of *Aloe ferox*. Shrubby Asteraceae increase as grazing reduces the palatable grassy component (mostly *Hyparrhenia hirta*) and subsequent erosion results. Heuweltjies not conspicuous, except in the south of the area. South of Bredasdorp this type is restricted and replaced by FFf 1 Elim Ferricrete Fynbos in wetter areas.

Geology & Soils Clays and loams derived from Bokkeveld Group shales, with Glenrosa and Mispah forms dominant. Land types mainly Fb.

Climate MAP 300–480 mm (mean: 380 mm), with a slight peak in winter (August), 49% of rain falling from May to August. Mean daily maximum and minimum temperatures 27.3°C and 5.6°C for January and July, respectively. Frost incidence about

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Figure 4.113 FRs 12 Central Rûens Shale Renosterveld: Renosterbos (*Elytropappus rhinocerotis*) shrublands south of Genadendal in the Overberg (Western Cape).

Distribution Western Cape Province: Eastern Rûens (Overberg) from Bredasdorp (Patryskraal) and the area of the Breede River near Swellendam, between the coastal limestone (and sandstone) belt in the south and vegetation types of the southern foothills of the Langeberg, encompassing the areas in the vicinity of Malgas and Heidelberg, to the Goukou River at Riversdale. Altitude 40–320 m.

Vegetation & Landscape Features Moderately undulating hills and plains supporting cupressoid and small-leaved, low to moderately tall grassy shrubland, dominated by renosterbos. The southern limits are often covered by a thin layer of calcrete. Little of this vegetation remains, but some thicker calcrete deposits, too thick to be ploughed, support mesotrophic asteraceous 'fynbos' with *Crassula expansa*, *Leucadendron linifolium* and *Nylandtia spinosa*. It is not known whether the thinner deposits supported renosterveld or intermediate communities. In some places, especially closer to the mountains (Langeberg), *Themeda triandra* grasslands are found (see Raitt 2005).

Geology & Soils Clays and loams derived from Bokkeveld Group shales with some contribution from Mesozoic Uitenhage Group sediments in the northeast; Glenrosa and Mispah forms dominant. Land types mainly Fb, Fc and Db.

Climate MAP 270–540 mm (mean: 385 mm), with an even distribution and a slight low from December to February. Mean daily maximum and minimum temperatures 26.9°C and 5.9°C for January and July, respectively. Frost incidence about 3 days per year. See also climate diagram for FRs 13 Eastern Rûens Shale Renosterveld (Figure 4.101).

Important Taxa Succulent Tree: *Aloe ferox* (d). Tall Shrub: *Rhus pallens* (d). Low Shrubs: *Athanasia trifurcata* (d), *Elytropappus rhinocerotis* (d), *Helichrysum petiolare* (d), *Hermannia flammea* (d), *H. saccifera* (d), *Oedera genistifolia* (d), *O. squarrosa* (d),

3 days per year. See also climate diagram for FRs 12 Central Rûens Shale Renosterveld (Figure 4.101).

Important Taxa Tall Shrub: *Rhus pallens* (d). Low Shrubs: *Aspalathus steudeliana* (d), *A. submissa* (d), *Asparagus capensis* var. *capensis* (d), *Athanasia dentata* (d), *A. trifurcata* (d), *Elytropappus rhinocerotis* (d), *Helichrysum petiolare* (d), *Hermannia flammea* (d), *H. saccifera* (d), *Oedera genistifolia* (d), *O. squarrosa* (d), *Printzia polifolia* (d), *Pteronia incana* (d), *Stoebe plumosa* (d), *Aspalathus campestris*, *A. pinguis* subsp. *pinguis*, *A. pycnantha*, *Relhania garnotii*. Succulent Shrubs: *Ruschia lineolata* (d), *Drosanthemum flavum*. Geophytic Herbs: *Geissorhiza nana*, *Romulea minutiflora*. Graminoids: *Cymbopogon pospischilii* (d), *Ficinia nigrescens* (d), *F. oligantha* (d), *Merxmuellera disticha* (d), *M. stricta* (d), *Themeda triandra* (d).

Endemic Taxa Low Shrubs: *Aspalathus barbigera*, *A. smithii*, *Relhania spathulifolia*. Succulent Shrubs: *Drosanthemum lavisii*, *Erepsia dubia*. Herb: *Arctotis dregei*. Geophytic Herb: *Moraea minuta*.

Conservation Critically endangered vegetation unit. Target of 27% cannot be attained since 87% of the area has already been transformed by cultivation. Small patches are conserved in the Agulhas National Park. Remnants are mainly on the sides of steeper hills. There is a notable absence of alien woody plants. Erosion very low and moderate.

References Boucher & Moll (1981), Cowling et al. (1988), Mustart et al. (1997), Von Hase et al. (2003), C. Boucher (unpublished data), N. Helme (unpublished data).

FRs 13 Eastern Rûens Shale Renosterveld

VT 46 Coastal Renosterbosveld (89%) (Acocks 1953). LR 63 South and South-west Coast Renosterveld (97%) (Low & Rebelo 1996). BHU 34 Riversdale Coast Renosterveld (53%), BHU 33 Overberg Coast Renosterveld (34%), BHU 19 Suurbraak Grassy Fynbos (10%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

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Figure 4.114 FRs 13 Eastern Rûens Shale Renosterveld: Island of renosterveld (with prominent *Elytropappus rhinocerotis* and *Stoebe plumosa*) and scattered emergent *Aloe ferox* (here at the western limit of its distribution) in the Overberg (Western Cape).

O. uniflora (d), *Stoebe plumosa* (d), *Acmadenia macropetala*, *Anthospermum prostratum*, *Aspalathus alpestris*, *A. calcarata*, *A. campestris*, *A. millefolia*, *A. pinguis* subsp. *pinguis*, *A. zeyheri*, *Diosma passerinoides*, *Metalasia pungens*, *Polhillia pallens*, *Relhania garnotii*, *Ursinia discolor*. Herbs: *Arctotis acaulis*, *Peucedanum striatum*. Geophytic Herbs: *Freesia caryophyllacea*, *Geissorhiza nana*, *Oxalis purpurea*, *Romulea minutiflora*. Succulent Herbs: *Duvalia elegans*, *Haworthia marginata*. Graminoids: *Cymbopogon pospischilii* (d), *Eragrostis curvula* (d), *Merxmuellera stricta* (d), *Themeda triandra* (d), *Ehrharta calycina*, *E. melicoides*, *Elegia recta*, *Festuca scabra*, *Koeleria capensis*, *Tribolium hispidum*.

Endemic Taxa Low Shrubs: *Agathosma gnidiiflora*, *Aspalathus grobleri*, *A. opaca* subsp. *pappeana*, *Gnidia ericoides*, *Lebeckia bowieana*, *Polhillia brevicalyx*, *Pteronia beckeoides*. Tall Shrub: *Aspalathus incompta*. Succulent Shrubs: *Drosanthemum vandermerwei*, *Trichodiadema pygmaeum*. Semiparasitic Shrub: *Thesium rufescens*. Geophytic Herb: *Hesperantha muirii*. Succulent Herbs: *Haworthia heidelbergensis*, *H. mutica*, *H. serrata*.

Conservation Critically endangered. Target of 27% cannot be attained since over 80% of the area has been transformed, mostly for cropland. Only patches on the steepest slopes remain in a more or less natural state. Small fractions conserved in the Bontebok National Park, De Hoop and Werner Frehse Nature Reserves as well as in the private Grootvadersbosch Conservancy. Invasion of alien woody plants does not seem to constitute a problem; only *Acacia cyclops* occurs in places. Erosion moderate and very low.

Remarks River valleys, watercourses and bottomlands support AZa 2 Cape Lowland Alluvial Vegetation dominated by *Acacia karroo*, *Aloe ferox*, *Buddleja saligna* and *Rhus pallens*. These are extensive, but have not been mapped so far.

References Muir (1929), Grobler & Marais (1967), Taylor (1970a), Boucher & Moll (1981), Rebelo et al. (1991), Von Hase et al. (2003), Raitt (2005), C. Boucher (unpublished data), N. Helme (unpublished data).

FRs 14 Mossel Bay Shale Renosterveld

VT 46 Coastal Renosterbosveld (76%) (Acocks 1953). South Coast Renosterveld (38%) (Moll & Bossi 1983). LR 63 South and South-west Coast Renosterveld (93%) (Low & Rebelo 1996). BHU 34 Riversdale Coast Renosterveld (64%), BHU 28 Blanco Fynbos/Renosterveld Mosaic (24%) (Cowling et al. 1999b, Cowling & Heijnis 2001). STEP Herbertsdale Renoster Thicket (46%), STEP Gouritz Valley Thicket (10%) (Vlok & Euston-Brown 2002).

Distribution Western Cape Province: Coastal plains and valleys from the Kruisrivier near Riversdale to Botterberg, west of the Robinson Pass, centred on the Gouritz River and bordered by mountains (Langeberg, Outeniqua) to the north and the N2 road to the south, except for a few small patches further south (south of Cooper). Altitude 120–360 m.

Vegetation & Landscape Features Undulating hills and tablelands, steeply dissected by rivers. The vegetation of the area is mainly a medium dense, medium tall cupressoid-leaved shrubland dominated by renosterbos, dotted by sparse, tall shrubs. Thicket patches and thicket elements are common, possibly because the landscape is more rugged than in the case of the Rûens shale renosterveld types, and therefore less prone to fire. Fire-safe habitats, such as steep slopes, gullies and termitaria have thicket clumps, dominated by *Euclea undulata*, *Putterlickia pyracantha* and *Rhus lucida*. Steep north-facing slopes have succulent thicket elements. The southern reaches may be covered with a calcrete layer bearing South Coast limestone fynbos elements.

Geology & Soils Clays and loams mostly derived from Bokkeveld Group shales as well as Uitenhage Group clastics in the west and east. Prismacutanic or pedocutanic diagnostic horizons occur in soils. Glenrosa and Mispah forms dominant. Land types mainly Db, Ea and Fc.

Climate MAP 270–620 mm (mean: 425 mm), even throughout the year with a slight low in December. Mean daily maximum and minimum temperatures 27.6°C and 6.1°C for January–February and July, respectively. Frost incidence about 3 days per year. See also climate diagram for FRs 14 Mossel Bay Shale Renosterveld (Figure 4.101).

Important Taxa Succulent Trees: *Aloe ferox*, *A. speciosa*. Tall Shrubs: *Diospyros dichrophylla*, *Rhus glauca*, *R. pterota*. Low Shrubs: *Aspalathus alpestris*, *Barleria pungens*, *Blepharis capensis*, *Carissa bispinosa* subsp. *bispinosa*, *Elytropappus rhinocerotis*, *Eriocephalus africanus* var. *africanus*, *Indigofera denudata*, *Metalasia pungens*, *Oedera genistifolia*, *Pentzia incana*, *Ursinia discolor*. Succulent Shrubs: *Aloe arborescens*, *Crassula perforata*, *Drosanthemum intermedium*. Woody Climber: *Asparagus racemosus*. Geophytic Herb: *Romulea luteoflora*. Succulent Herbs: *Carpobrotus acinaciformis*, *Senecio crassulaefolius*. Graminoids: *Brachiaria serrata*, *Ehrharta calycina*, *Ischyrolepis capensis*, *Pentaschistis eriostoma*, *P. pallida*, *Sporobolus africanus*, *Themeda triandra*.

Endemic Taxa Low Shrubs: *Anisodontea pseudocapensis*, *Aspalathus obtusifolia*, *Polhillia connata*, *Ruellia pilosa*, *Salvia muirii*. Succulent Herbs: *Haworthia chloracantha* var. *denticulifera*, *H. chloracantha* var. *subglauca*, *H. magnifica* var. *dekenahii*, *H. magnifica* var. *splendens*, *H. retusa*.

Conservation Endangered. Target 27%. None conserved in statutory conservation areas and only small patches protected in Langeberg-oos mountain catchment area. Some 58% has been transformed (croplands and pastures). Erosion mainly moderate and high, but with some areas ranking as very low.

Remarks Overgrazing can eliminate grasses, resulting in a grass-free shrubland or thicket. FFc 1 Swellendam Silcrete Fynbos can be converted to Mossel Bay Shale Renosterveld by overgrazing.

References Muir (1929), Boucher & Moll (1981), Rebelo et al. (1991), H.C. Taylor (unpublished data).

FRs 15 Swartberg Shale Renosterveld

VT 70 False Macchia (54%), VT 26 Karroid Broken Veld (42%) (Acocks 1953). South Coast Renosterveld (60%), Karroid Shrublands (37%) (Moll & Bossi 1983). Grassy Renoster Shrubland (Campbell 1985). LR 63 South and South-west Coast Renosterveld (62%), LR 54 Central Lower Nama Karoo (26%) (Low & Rebelo 1996). BHU 43 Kango Inland Renosterveld (65%), BHU 68 Prince Albert Broken Veld (28%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western and Eastern Cape Provinces: Mainly northern slopes of the Groot Swartberg and some parallel ridges in the Oukloof and Droëkloof from near Prince Albert in the west to Vartjiesrivier in the east; an outlier further west on the Swartberg in the upper reaches of the Waterkloofrivier catchment between Elandspad and Kliphuisvlei (above and east of Gamkaskloof or Die Hel). Altitude 750–1 200 m.

Vegetation & Landscape Features Steep and gentle intermontane valleys with low, medium dense cupressoid-leaved shrubland having an open grassy understorey and dominated by renosterbos. Heuweltjies are rare.

Geology & Soils The soils derived from several shale sources within the Table Mountain Group (particularly the Nardouw Subgroup) as well as the Witteberg and Bokkeveld Groups of the Cape Supergroup that underlie this area. Prismacutanic and pedocutanic and Glenrosa or Mispah forms are prominent. Land types mainly Ib, Ic and Fc.

Climate MAP 150–440 mm (mean: 285 mm), even throughout the year. Mean daily maximum and minimum temperatures 30.0°C and 2.3°C for January and July, respectively. Frost incidence 10–30 days per year. See also climate diagram for FRs 15 Swartberg Shale Renosterveld (Figure 4.101).

Important Taxa ([T]Cape thickets) Succulent Tree: *Aloe ferox*. Tall Shrubs: *Buddleja salviifolia*[T], *Cliffortia strobilifera*, *Diospyros pallens*[T], *Dodonaea viscosa* var. *angustifolia*, *Euclea undulata*[T], *Rhus lucida*[T], *R. pallens*[T], *R. pyroides*[T], *R. undulata*[T]. Low Shrubs: *Athanasia trifurcata* (d), *Chrysocoma ciliata* (d), *Elytropappus rhinocerotis* (d), *Oedera genistifolia* (d), *Polygala bracteolata* (d), *Pteronia incana* (d), *Anthospermum aethiopicum*, *Ballota africana*, *Cliffortia ilicifolia*, *Dimorphotheca cuneata*, *Diospyros austro-africana*, *Eriocephalus africanus* var. *africanus*, *Felicia filifolia* subsp. *filifolia*, *Lebeckia pungens*, *Leysera gnaphalodes*, *Oedera squarrosa*, *Pteronia glauca*, *P. pallens*. Woody Succulent Climber: *Zygophyllum debile*. Semiparasitic Epiphytic Shrub: *Viscum capense*. Herbs: *Conium chaerophylloides*, *Galium tomentosum*, *Sutera patriotica*. Graminoids: *Ehrharta calycina*, *E. erecta*, *Eragrostis curvula*, *Karroochloa purpurea*.

Conservation Least threatened. Target 29%. Statutorily conserved in the Groot Swartberg (8%), with additional 1% protected in the Swartberg East mountain catchment area. Only 3% transformed (cultivation). Erosion very low and low.

Remark This is a poorly known vegetation type. Unmapped portions of this unit have been subsumed into FFb 3 Central Inland Shale Band Vegetation.

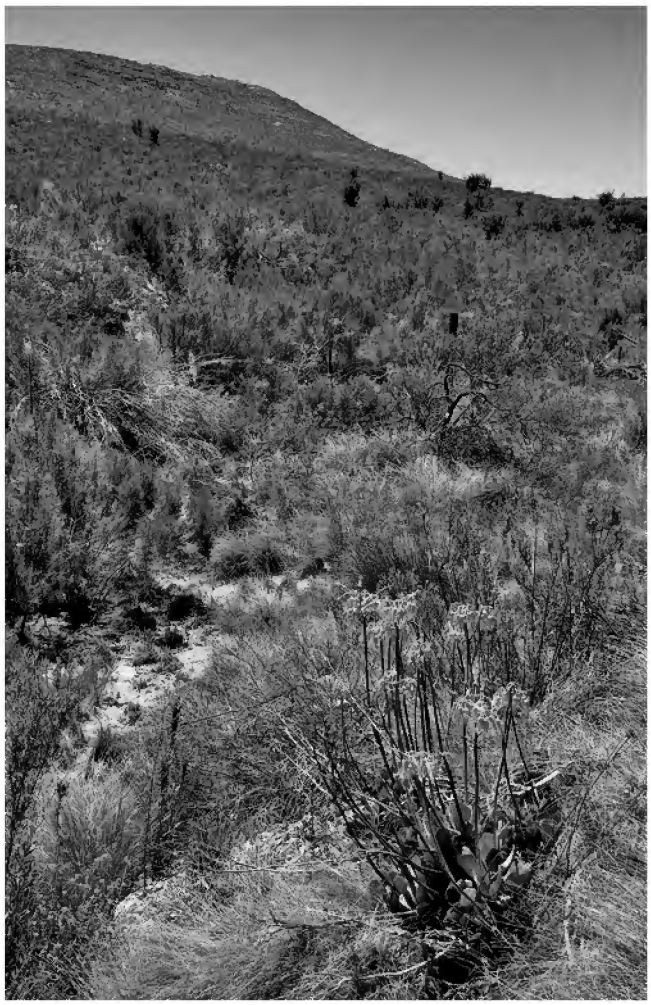

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Figure 4.115 FRs 16 Uniondale Shale Renosterveld: Renosterbos shrublands with *Elytropappus rhinocerotis*, *Athanasia furcata* and *Cotyledon orbiculata* (in the foreground) in the Klein Langkloof Valley along the northern foot of the Outeniqua Mountains (Western Cape).

FRs 16 Uniondale Shale Renosterveld

VT 43 Mountain Renosterbosveld (50%), VT 26 Karroid Broken Veld (27%) (Acocks 1953). Karroid Shrublands (48%), South Coast Renosterveld (24%), Mosaic of South Coast Renosterveld (19%) (Moll & Bossi 1983). Grassy Renoster Shrubland (Campbell 1985). LR 63 South and South-west Coast Renosterveld (49%), LR 54 Central Lower Nama Karoo (23%) (Low & Rebelo 1996). BHU 44 Uniondale Inland Renosterveld (32%), BHU 98 Willowmore Xeric Succulent Thicket (21%) (Cowling et al. 1999b, Cowling & Heijnis 2001). STEP Willowmore Renoster Thicket (35%) (Vlok & Euston-Brown 2002).

Distribution Western and Eastern Cape Provinces: Little Karoo from Sebrasfontein (south of Oudtshoorn) to Uniondale on the northern slopes of the Outeniqua Mountains, lower southern slopes of the Kammanassie Mountains, northern slopes of the western end of the Kouga Mountains as well as ridges, plateaus and valleys to Willowmore in the north; a few outliers in the Grootrivierberge, west of Naroegas Poort. Altitude 500–1 150 m.

Vegetation & Landscape Features Intermontane valleys and lower slopes covered with low, medium dense, cupressoid-leaved shrubland having an open grassy understorey, and dominated by renosterbos. North-facing slopes have thicket clumps. Eastern extent very much limited by fire-retardant thicket vegetation, and thus associated mainly with the fynbos areas at higher altitudes.

Geology & Soils Clays and loams derived from Bokkeveld (and Witteberg) Group shales. Glenrosa and Mispah forms prominent. Land types mainly Fc and Fb.

Climate MAP 170–660 mm (mean: 350 mm), even throughout the year with a slight peak in March. Mean daily maximum and minimum temperatures 29.6°C and 2.4°C for January and July, respectively. Frost incidence 10–40 days per year. See also climate diagram for FRs 16 Uniondale Shale Renosterveld (Figure 4.101).

Important Taxa Small Tree: *Acacia karroo* (d). Succulent Tree: *Aloe ferox* (d). Tall Shrubs: *Rhus lucida* (d), *Diospyros austro-africana*, *Dodonaea viscosa* var. *angustifolia*, *Euclea undulata*. Low Shrubs: *Elytropappus rhinocerotis* (d), *Oedera squarrosa* (d), *Carissa bispinosa* subsp. *bispinosa*, *Chrysocoma oblongifolia*, *Felicia filifolia* subsp. *filifolia*, *Galenia africana*, *Helichrysum asperum* var. *albidulum*, *Lessertia fruticosa*, *Lotononis nutans*, *Pteronia incana*, *Selago saxatilis*, *Zygophyllum spinosum*. Succulent Shrubs: *Aloe perfoliata* (d), *A. microstigma* subsp. *microstigma*, *Crassula dependens*, *Drosanthemum lique, Glottiphyllum salmii*. Semiparasitic Shrub: *Thesium strictum*. Herbs: *Lepidium africanum* subsp. *africanum*, *Limeum aethiopicum* subsp. *aethiopicum*. Geophytic Herbs: *Drimia anomala*, *D. intricata*, *Romulea jugicola*. Succulent Herb: *Crassula muscosa*. Graminoids: *Aristida diffusa*, *Ehrharta calycina*, *Melica decumbens*.

Endemic Taxa Low Shrub: *Amphithalea vlokii*. Succulent Shrubs: *Carruanthus ringens*, *Glottiphyllum oligocarpum*. Geophytic Herb: *Tritonia chrysantha*.

Conservation Least threatened. Target 29%. Only a few patches (less than 1%) are protected in the private Sunnyside Game Farm and in Welbedacht State Forest. Some 15% transformed (cultivation). Woody aliens include *Hakea sericea* and *Pinus pinaster*. Erosion mainly high and moderate.

Remark This is a poorly known vegetation type.

References Boucher & Moll (1981), Vlok & Euston-Brown (2002).

FRs 17 Langkloof Shale Renosterveld

VT 70 False Macchia (92%) (Acocks 1953). Mesic Grassy Fynbos (23%) (Moll & Bossi 1983). LR 63 South and South-west Coast Renosterveld (48%), LR 65 Grassy Fynbos (33%) (Low & Rebelo 1996). BHU 29 Langkloof Fynbos/Renosterveld Mosaic (74%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western and Eastern Cape Provinces: Narrow belt from Herold on the northern side of the Outeniqua Mountains to Kykoe, then descending along the upper reaches of the Keurbooms River Valley, south of the Prince Alfred Pass, to Vleitjie se Berg; in the Langkloof Valley from Harmonie via Avontuur to Haarlem and further from Krakeelrivier via Joubertina and Kareedouw to Salielaagte. Small outlier at Brandhoek northeast of Joubertina. Altitude 220–950 m.

Vegetation & Landscape Features Intermontane valleys and lower slopes with low, medium dense graminoid, dense cupressoid-leaved shrubland, dominated by renosterbos and surrounded by fynbos.

Geology & Soils A very narrow east-west distribution of clays and loams derived from shales of the Nardouw Subgroup of the Table Mountain Group as well as the Ceres Subgroup of the Bokkeveld Group. Prismacutanic and pedocutanic and Glenrosa and Mispah forms are prominent. Land types mainly Db, Fa and Bb.

Climate MAP 280–770 mm (mean: 505 mm), relatively even with a bimodal peak in March and October–November. Mean daily maximum and minimum temperatures 27.9°C and 4.6°C for January–February and July, respectively. Frost incidence 2–10 days per year. See also climate diagram for FRs 17 Langkloof Shale Renosterveld (Figure 4.101).

Important Taxa Tall Shrubs: *Metalasia densa*, *Passerina corymbosa*. Low Shrubs: *Anthospermum aethiopicum*, *A. galioides* subsp. *galioides*, *Argyrolobium pauciflorum*, *Aspalathus nigra*, *Chaetacanthus setiger*, *Eriocephalus africanus* var. *africanus*, *Helichrysum anomalum*, *H. teretifolium*, *Hermannia flammea*, *Indigofera denudata*, *Passerina rubra*, *Pentzia dentata*, *Selago mediocris*, *Senecio hollandii*. Herb: *Hibiscus pusillus*. Herbaceous Climber: *Thunbergia capensis*. Graminoids: *Brachiaria serrata*, *Cymbopogon marginatus*, *Cynodon dactylon*, *Ehrharta calycina*, *E. capensis*, *Festuca scabra*, *Ficinia tristachya*, *Helictotrichon hirtulum*, *Merxmuellera stricta*, *Pentaschistis angustifolia*, *Sporobolus africanus*, *Themeda triandra*.

Endemic Taxon Herb: *Senecio euryopoides*.

Conservation Endangered. Target 29%. None conserved in statutory or private conservation areas. Some 61% transformed (mainly fruit orchards and pastures). Important woody aliens are *Hakea sericea* and *Pinus pinaster*. Erosion very low and low.

Remark This is a poorly known vegetation type. Unmapped portions have been included within the mapped patches of FFb 6 Eastern Coastal Shale Band Vegetation.

References Boucher & Moll (1981), H.C. Taylor (unpublished data).

FRs 18 Baviaanskloof Shale Renosterveld

VT 70 False Macchia (47%), VT 25 Succulent Mountain Scrub (Spekboomveld) (45%) (Acocks 1953). Mesic Grassy Fynbos (99%) (Moll & Bossi 1983). LR 65 Grassy Fynbos (99%) (Low & Rebelo 1996). BHU 73 Baviaanskloof Mountain Fynbos Complex (98%) (Cowling et al. 1999b, Cowling & Heijnis 2001). STEP Baviaans Renoster Thicket (96%) (Vlok & Euston-Brown 2002).

Distribution Eastern Cape Province: Two relatively small groups of digitally shaped lower hillslopes dissected by many ravines (kloofs) containing AT 3 Groot Thicket on the southern side of the Baviaanskloof Valley from Voorkloof to Vleikloof in the west and from Kleinkommandokloof to Drinkwaterkloof in the east. Altitude 600–1 150 m.

Vegetation & Landscape Features Flat, lower mountain bases covered with low, medium dense, cupressoid-leaved shrubland, dominated by renosterbos and with graminoid undergrowth. Rocky areas have small localised thicket patches. This renosterveld type often grades into the surrounding fynbos.

Geology & Soils Often skeletal clays and loams derived from shales of the Nardouw Subgroup (Table Mountain Group). Glenrosa and Mispah forms prominent. Land types mainly Ib and Fb.

Climate MAP 200–620 mm (mean: 365 mm), even throughout the year, with a peak in March. Mean daily maximum and minimum temperatures 27.9°C and 2.5°C for February and July, respectively. Frost incidence 10–30 days per year. See also climate diagram for FRs 18 Baviaanskloof Shale Renosterveld (Figure 4.101).

Important Taxa Succulent Tree: *Aloe ferox*. Low Shrubs: *Elytropappus rhinocerotis* (d), *Chascanum cuneifolium*, *Passerina obtusifolia*, *Phylica axillaris*, *Pteronia incana*. Herb: *Hibiscus aethiopicus*. Graminoids: *Eragrostis curvula*, *E. obtusa*, *Eustachys paspaloides*, *Themeda triandra*.

Endemic Taxon Succulent Shrub: *Delosperma esterhuyseniae*.

Conservation Least threatened. Target 29%. It is statutorily conserved in the Guerna (16%) and Baviaanskloof Wilderness Areas (4%), with some small patches also conserved on private land (Beakosneck). The unit has not experienced notable transformation so far, except for the occurrence of aliens such as *Acacia mearnsii, A. saligna*, *Pinus pinaster* and *Opuntia ficus-indica*. Erosion mainly low and moderate.

Remark This is a rare and poorly studied vegetation type.

References Boucher & Moll (1981), Euston-Brown (1995), Vlok & Euston-Brown (2002).

FRs 19 Humansdorp Shale Renosterveld

VT 70 False Macchia (91%) (Acocks 1953). Mosaic of South Coast Renosterveld (83%) (Moll & Bossi 1983). LR 63 South and South-west Coast Renosterveld (89%) (Low & Rebelo 1996). BHU 30 Kromme Fynbos/Renosterveld Mosaic (90%) (Cowling et al. 1999b, Cowling & Heijnis 2001). STEP Kabeljous Renoster Thicket (17%), STEP Rocklands Renoster Thicket (8%) (Vlok & Euston-Brown 2002).

Distribution Eastern Cape Province: Three swathes: from Jeffreys Bay and Marina Glades near the coast inland past Humansdorp to the lower reaches of the Dieprivier near Two Streams; the Mondplaas/Mondhoek area near the mouth of the Gamtoos River stretching inland in a series of patches south of the Gamtoos River to west of Patensie; between thicket and fynbos types from Burghley Hills to Rocklands and the Dell to Nooitgedacht southwest of Uitenhage. Coastal forelands from Humansdorp to Port Elizabeth. Altitude 20–360 m.

Vegetation & Landscape Features Moderately undulating plains and undulating hills supporting vegetation composed of low, medium dense graminoid, dense cupressoid-leaved shrubland, dominated by renosterbos. There are both grassland and shrubland forms of the renosterveld present, probably depending on grazing and fire regimes. In wetter areas (> 550 mm) it grades into FFt 2 Loerie Conglomerate Fynbos. Thicket patches are common on termitaria (heuweltjies are absent) and in fire-safe enclaves, especially in the east. It is dominated by *Aspalathus nivea* in the post-fire, early seral stages.

Geology & Soils Clays and loams derived from the Ceres Subgroup of the Bokkeveld Group shales. Plinthic catenas prominent. Land types mainly Ca and Bb.

Climate MAP 500–850 mm (mean: 630 mm), peaking slightly in March, but otherwise even. Mean daily maximum and minimum temperatures 25.1°C and 7.5°C for February and July, respectively. Frost incidence about 3 days per year. See also climate diagram for FRs 19 Humansdorp Shale Renosterveld (Figure 4.101).

Important Taxa ([W]Wetlands) Succulent Tree: *Aloe africana*. Tall Shrubs: *Cliffortia strobilifera*, *Metalasia densa*, *Morella serrata*. Low Shrubs: *Elytropappus rhinocerotis* (d), *Helichrysum anomalum* (d), *Oedera genistifolia*, (d), *Anthospermum galioides* subsp. *galioides*, *Barleria pungens, Chaetacanthus setiger*, *Clutia rubricaulis*, *Euryops munitus, Felicia filifolia* subsp. *filifolia*, *Hermannia flammea*, *Indigofera denudata*, *I. heterophylla*, *Lotononis acuminata*, *Metalasia aurea, Muraltia alopecuroides*, *Passerina rubra*, *Pelargonium sidoides, Tephrosia capensis*. Herbaceous Climber: *Thunbergia capensis*. Herbs: *Arctotis acaulis*, *Berkheya heterophylla* var. *radiata*, *Centella asiatica*[W], *Gazania linearis*, *Gerbera piloselloides*, *Helichrysum nudifolium*, *Hibiscus pusillus*, *Senecio othonniflorus*. Geophytic Herbs: *Bobartia orientalis*, *Geissorhiza heterostyla*, *Ledebouria cooperi, Oxalis punctata*, *O. smithiana*, *Satyrium membranaceum*. Graminoids: *Eustachys paspaloides* (d), *Themeda triandra* (d), *Aristida junciformis* subsp. *galpinii*, *Brachiaria serrata*, *Cymbopogon marginatus*, *Cynodon dactylon*, *Eragrostis capensis*, *E. curvula*, *Ficinia nigrescens*, *F. tristachya*, *Merxmuellera disticha*, *Paspalum dilatatum*, *Pentaschistis pallida, Restio tetragonus*, *Sporobolus africanus*, *Tribolium hispidum*, *Tristachya leucothrix*.

Endemic Taxa Succulent Shrubs: *Delosperma patersoniae*, *Trichodiadema fourcadei*. Geophytic Herb: *Cyrtanthus wellandii*.

L. Mucina

Figure 4.116 FRs 19 Humansdorp Shale Renosterveld: Renosterveld shrubland with *Elytropappus rhinocerotis* and *Oedera genistifolia* on coastal flats near Jeffreys Bay (Eastern Cape).

Conservation Endangered. Target 29%. None conserved in statutory conservation areas and only 6% enjoys protection on private land (Thaba Manzi and Lombardini Game Farms). Some 61% already transformed (cultivation). Erosion very low and low.

Remark Locally, thicket is burnt and converted to renosterveld for grazing.

References Boucher & Moll (1981), Cowling (1984), Vlok & Euston-Brown (2002).

9.2.2 Granite and Dolerite Renosterveld

Granite renosterveld is the second most widespread renosterveld group, comprising 6% the area of renosterveld. Only three units, in the Kamiesberg, Swartland and at Robertson, are recognised. All are quite distinct and unrelated to one another.

Granite renosterveld has very strong affinities with granite fynbos. This edaphic transition appears to have been responsible for a fynbos 'derivation' of renosterveld on the West Coast, or at least a high proportion of fynbos elements within the renosterveld (chiefly geophytes). Prominent on granites are high bulb diversity and a very strong forest-thicket element, especially on rocky outcrops and fire-safe habitats which abound in granite landscapes.

Dolerite renosterveld is confined to the Western Escarpment between Nieuwoudtville and Calvinia, with outliers to Sutherland. Like granite renosterveld, this has a high bulb diversity, with Nieuwoudtville being recognised as the bulb capital of the world—an unusually high proportion of species within the vegetation type are geophytes, and exceptional bulb densities can be found here.

FRg 1 Namaqualand Granite Renosterveld

VT 43 Mountain Renosterbosveld (63%), VT 33 Namaqualand Broken Veld (Acocks 1953). LR 59 North-western Mountain Renosterveld (53%), LR 56 Upland Succulent Karoo (39%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Namaqualand, east of Kamieskroon and northeast of Garies in the higher-altitude parts of the Kamiesberg area from Os Plaat se Berge and the Dounabesberge in the north to Stalberg and Grasberg in the south and including a central area around Leliefontein. The most easterly extension is in the vicinity of Paulshoek. Embedded within this unit are several patches of generally highest-altitude FFg 1 Kamiesberg Granite Fynbos. Altitude 1 100–1 450 m.

Vegetation & Landscape Features Plateaus, low mountains and broken veld of typical granite landscapes, covered with dense, 1–1.5 m tall shrublands dominated by renosterbos (*Elytropappus rhinocerotis*) and other, mainly asteraceous (*Euryops*, *Arctotis*) shrubs. Overgrazing increases the cover of karoo elements. Abandoned ploughed fields on the plateaus present spectacular annual floral displays.

Geology & Soils In this area granitic gneiss of the Stalhoek Complex, the Kamieskroon Gneiss and the Nababeep Gneiss is partly overlain by quartzite and other metasediments of the Bitterfontein

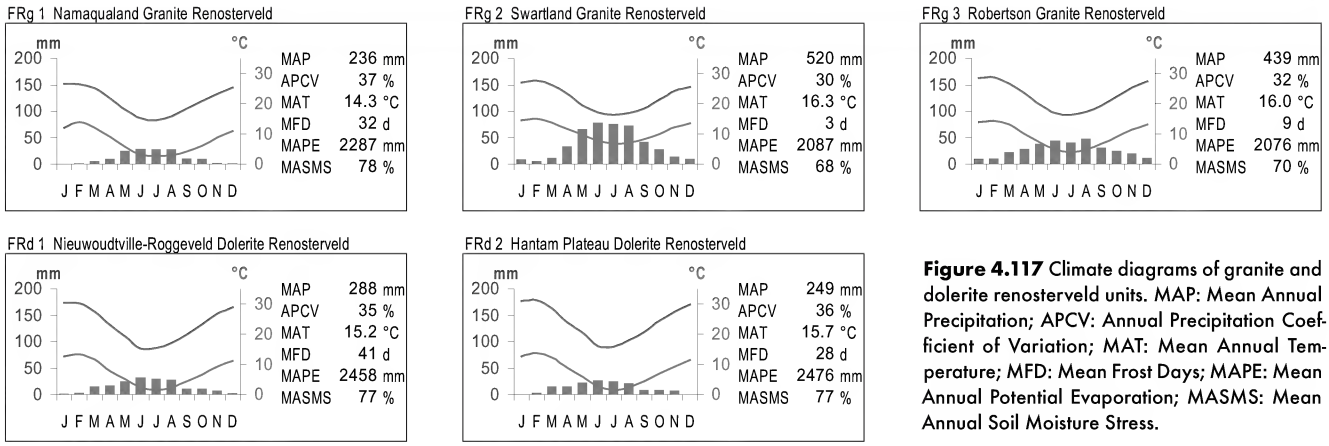

Figure 4.117 Climate diagrams of granite and dolerite renosterveld units. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days; MAPE: Mean Annual Potential Evaporation; MASMS: Mean Annual Soil Moisture Stress.

Formation (Bushmanland Group). The above Mokolian age rocks form level to gentle rocky slopes. The soils are sandy; yellow-brown to brown loamy sand. Land types mainly Ic, IB and Ag.

Climate MAP 130–370 mm (mean: 235 mm), peaking from May to August. This is the most arid of the renosterveld types. Mean daily maximum and minimum temperatures 26.6°C and 2.7°C for January and July, respectively. Frost incidence 10–30 days per year. See also climate diagram for FRg 1 Namaqualand Granite Renosterveld (Figure 4.117).

Important Taxa Tall Shrubs: *Dodonaea viscosa* var. *angustifolia* (d), *Montinia caryophyllacea*, *Nylandtia spinosa*, *Rhus undulata*. Low Shrubs: *Elytropappus rhinocerotis* (d), *Clutia imbricata*, *Hermannia meyeriana*, *Lessertia microcarpa*, *Phylica montana*, *Pteronia pillansii*, *Rhus horrida*. Succulent Shrub: *Othonna retrorsa*. Herbs: *Arctotheca calendula* (d), *Cotula leptalea* (d), *Leysera gnaphalodes* (d), *L. tenella* (d), *Gorteria diffusa* subsp. *calendulacea* (d), *Gazania leiopoda*, *Gymnodiscus capillaris*, *Heliophila schulzii*, *Manulea altissima*, *Ursinia speciosa*. Geophytic Herbs: *Babiana curviscapa*, *Bulbinella ciliolata*, *Ferraria kamiesbergensis*, *Geissorhiza namaquensis*, *Haemanthus amarylloides* subsp. *polyanthus*, *Hesperantha flexuosa*, *Hessea stenosiphon*, *Ixia latifolia* var. *ramulosa*, *Lachenalia unicolor*, *Moraea kamiesensis*, *M. rivulicola*, *Oftia revoluta*, *Oxalis ambigua*, *O. comosa*, *O. furcillata*, *Romulea citrina*, *R. kamisensis*, *R. namaquensis*, *R. neglecta*, *Tritonia kamisbergensis*.

Biogeographically Important Taxa (all Kamiesberg endemics, [W]Wetlands) Low Shrubs: *Antithrixia flavicoma*, *Aspalathus angustifolia* subsp. *robusta*, *Felicia diffusa* subsp. *khamiesbergensis*, *Muraltia rigida*. Herb: *Centella tridentata* var. *dregeana*. Geophytic Herbs: *Crocosmia fucata*, *Disa macrostachya*, *Hesperantha latifolia*, *Moraea kamiesmontana*, *Romulea pearsonii*[W].

Endemic Taxa Low Shrubs: *Euryops subcarnosus* subsp. *minor*, *Lotononis polycephala*, *Otholobium hamatum*. Succulent Shrubs: *Cheiridopsis pearsonii*. Herb: *Ursinia* sp. nov. ('*kamiesbergensis*') (*Mucina & Swelankomo 060905/2* STEU). Geophytic Herbs: *Haemanthus graniticus*, *Moraea longiflora*, *M. pendula*, *Oxalis kamiesbergensis*.

Conservation Least threatened. Target 27%. None conserved in statutory or private conservation areas. About 5% transformed (cultivation), but large portions suffer from heavy overgrazing. Erosion moderate and low.

Remark 1 This unit and FFg 1 Kamiesberg Granite Fynbos form the core of the Kamiesberg Centre of Endemism (Van Wyk & Smith 2001), which also comprises parts of the SKn 6 Kamiesberg Mountains Shrubland. The boundary between fynbos and renosterveld in this unit is determined by both rainfall and the composition of the granite, so that clay-rich south-facing slopes may contain renosterveld up to 1 500 m. The lower boundary with karoo is often diffuse, with karoo incursions on northern slopes, shallow soils and heuweltjies, and renosterveld extending into karoo on deeper soils, southern slopes and wetter facies. Overgrazing increases the cover of karroid elements, leading to replacement of renosterveld by karoo.

References Adamson (1958), Boucher & Moll (1981), Van Wyk & Smith (2001).

K. Phillips

Figure 4.118 FRg 1 Namaqualand Granite Renosterveld: Spring-floral display of *Arctotis*, *Cotula*, *Ursinia* and *Grielum humifusum* on old fields dotted by renosterbos shrubs on a plateau north of Leliefontein, in the Kamiesberg Mountains, Namaqualand (Northern Cape).

FRg 2 Swartland Granite Renosterveld

VT 46 Coastal Renosterbosveld (66%), VT 47 Coastal Macchia (30%) (Acocks 1953). LR 62 West Coast Renosterveld (77%), LR 68 Sand Plain Fynbos (22%) (Low & Rebelo 1996). BHU 31 Swartland Coast Renosterveld (59%), BHU 32 Boland Coast Renosterveld (32%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Discrete areas in the Swartland and

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Figure 4.119 FRg 2 Swartland Granite Renosterveld: Bulb-rich veld dominated by *Lachenalia pustulata* in the Tienie Versveld Flower Reserve near Darling (Western Cape).

Boland: largest patch centred on Darling from Ratelberg in the north to Dassenberg near Mamre and Pella; several centred on Malmesbury from Darmstadt in the north to the lower slopes of the Perdeberg (and small patches to the west towards Atlantis); east of Wellington from Micha to Valencia, lower surrounds of Paarl Mountain; Joostenberg, Muldersvlei, Bottelaryberg, Papegaaiberg (Stellenbosch West), to Firgrove and northern Somerset West. Altitude 50–350 m.

Vegetation & Landscape Features Moderate foot slopes and undulating plains supporting a mosaic of grasslands/herblands and medium dense, microphyllous shrublands dominated by renosterbos. Groups of small trees and tall shrubs are associated with heuweltjies and rock outcrops. The boundary with FFg 2 Boland Granite Fynbos is diffuse and patchy.

Geology & Soils Coarse sandy to loamy soils of a variety of forms ranging from Glenrosa and Mispah, to prismacutanic and pedocutanic diagnostic horizons to red-yellow apedal soils—all derived from Cape Granite. The soils can contain a considerable volume of moisture in winter and spring. Land types mainly Fa, Ca, Db and Ac.

Climate MAP 360–790 mm (mean: 520 mm), peaking from May to August. Mists common in winter. This is the wettest renosterveld unit. Mean daily maximum and minimum temperatures 27.7°C and 6.7°C for February and July, respectively. Frost incidence about 3 days per year. See also climate diagram for FRg 2 Swartland Granite Renosterveld (Figure 4.117).

Important Taxa ([T]Cape thickets) Tall Shrubs: *Euclea racemosa* subsp. *racemosa*[T] (d), *Olea europaea* subsp. *africana*[T] (d), *Putterlickia pyracantha*[T] (d), *Rhus laevigata*[T] (d), *Aspalathus acuminata* subsp. *acuminata*, *Chrysanthemoides monilifera*, *Diospyros glabra*[T], *Dodonaea viscosa* var. *angustifolia*, *Myrsine africana*[T], *Passerina corymbosa*, *Rhus angustifolia*[T], *R. crenata*[T], *R. tomentosa*[T], *R. undulata*[T], *Wiborgia obcordata*. Low Shrubs: *Anthospermum aethiopicum* (d), *Elytropappus rhinocerotis* (d), *Eriocephalus africanus* var. *africanus* (d), *Felicia filifolia* subsp. *filifolia* (d), *Maytenus oleoides* (d), *Salvia lanceolata* (d), *Anthospermum galioides* subsp. *galioides*, *Aspalathus hispida*, *Asparagus rubicundus*, *Athanasia trifurcata*, *Chironia baccifera*, *Erica paniculata*, *Galenia africana*, *Gnidia squarrosa*, *Helichrysum cymosum*, *H. dasyanthum*, *H. revolutum*, *H. teretifolium*, *Hermannia alnifolia*, *H. hyssopifolia*, *H. prismatocarpa*, *Leucadendron lanigerum* var. *lanigerum*, *Lobostemon argenteus*, *L. fruticosus*, *Nenax hirta* subsp. *hirta*, *Oftia africana*, *Phylica thunbergiana*, *Rhus dissecta*, *R. rosmarinifolia*, *Salvia africana-caerulea*, *Stoebe cinerea*. Succulent Shrub: *Lampranthus sociorum*. Woody Climbers: *Cissampelos capensis*, *Microloma sagittatum*. Herbs: *Helichrysum crispum* (d), *Annesorhiza macrocarpa*, *Cotula turbinata*, *Hebenstretia paarlensis*, *Lichtensteinia obscura*, *Stachys aethiopica*. Geophytic Herbs: *Mohria caffrorum* (d), *Chlorophytum undulatum*, *Geissorhiza monanthos*, *Moraea papilionacea*, *Oxalis obtusa*, *O. pes-caprae*, *O. purpurea*, *Pelargonium longifolium*, *Romulea eximia*, *R. rosea*, *Sparaxis parviflora*, *Watsonia borbonica* subsp. *borbonica*. Succulent Herb: *Crassula capensis*. Herbaceous Climber: *Cynanchum africanum*. Graminoids: *Ehrharta calycina* (d), *E. villosa* var. *villosa* (d), *Ischyrolepis gaudichaudiana* (d), *Cymbopogon marginatus*, *Ehrharta longiflora*, *E. ottonis*, *E. thunbergii*, *Ischyrolepis capensis*, *Thamnochortus bachmannii*, *Themeda triandra*, *Tribolium uniolae*.

Endemic Taxa Low Shrubs: *Agathosma hispida*, *A. latipetala*, *Aspalathus glabrata*, *A. rycroftii*. Succulent Shrubs: *Antimima menniei*, *Erepsia hallii*, *Lampranthus citrinus*, *L. scaber*, *Phyllobolus suffruticosus*, *Ruschia klipbergensis*. Herbs: *Arctopus dregei*, *Oncosiphon glabratum*. Geophytic Herbs: *Babiana pygmaea*, *B. regia*, *B. rubrocyanea*, *Geissorhiza darlingensis*, *G. eurystigma*, *G. malmesburiensis*, *G. mathewsii*, *G. radians*, *Haemanthus pumilio*, *Ixia aurea*, *I. curta*, *Lachenalia purpureocaerulea*, *Moraea amissa*, *Oxalis stictocheila*, *Watsonia humilis*.

Conservation This is a critically endangered vegetation unit of which almost 80% has already been transformed due to prime quality of the land for agriculture (vineyards, olive orchards, pastures) and also by urban sprawl. Hence the conservation target of 26% remains unattainable. Only very small portions (0.5%) enjoy statutory protection in the Paarl Mountain Nature Reserve and Pella Research Site, and also (2%) in the Paardenberg, Tienie Versveld Flower Reserve near Darling and in the Duthie Nature Reserve in Stellenbosch. Alien grasses are particularly pervasive, the most important being *Lolium multiflorum*, *Avena fatua* and *Bromus diandrus* (Musil et al. 2005). Alien woody species include *Acacia saligna*, *Pinus pinaster* as well as various species of *Eucalyptus*. Erosion very low, low and moderate.

Remarks The grassland phases of this vegetation unit as well as the rocky outcrops are particularly rich in geophytes. Several regional and local endemic taxa are shared with FRs 9 Swartland Shale Renosterveld.

References Acocks (1935), Boucher & Moll (1981), Boucher (1983, 1987, 1999b), Jacobs (1984), Landman & Nel (1989), Boucher & Rode (1994, 1999), Nel (1995), Von Hase et al. (2003), Musil et al. (2005), N. Helme (unpublished data).

FRg 3 Robertson Granite Renosterveld

VT 26 Karroid Broken Veld (74%), VT 69 Macchia (26%) (Acocks 1953). LR 61 Central Mountain Renosterveld (99%) (Low & Rebelo 1996). Central Mountain Renosterveld (97%) (Moll & Bossi 1983). BHU 38 Ashton Inland Renosterveld (96%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Extremely limited area: confined to low altitudes of the Tierberg north of La Colline near Robertson in the Breede River Valley. Altitude 250–850 m.

Vegetation & Landscape Features Gentle to steep slopes of a granite dome, with fairly dense 1–2 m tall, closed grassy shrubland with a greater than average succulent element and with scattered small trees. Bulbs are lacking diversity and grasses are currently dominant. Heuweltjies are present, but do not appear as a prominent feature. This unit is largely surrounded by shale renosterveld at lower elevations. At upper elevations, especially in the south, it grades into granite fynbos.

Geology & Soils Loamy soils, primarily of Glenrosa and Mispah forms derived from the Robertson Pluton of the Cape Granite Suite. Land type mainly Fb.

Climate MAP 360–740 mm (mean: 440 mm), with a slight peak from May to August. Mean daily maximum and minimum temperatures 28.7°C and 4.0°C for February and July, respectively. Frost incidence 6–10 days per year. See also climate diagram for FRg 3 Robertson Granite Renosterveld (Figure 4.117).

Important Taxa ([T]Cape thickets) Tall Shrubs: *Dodonaea viscosa* var. *angustifolia* (d), *Euclea undulata*[T], *Euryops tenuissimus*, *Myrsine africana*[T], *Olea europaea* subsp. *africana*[T], *Rhus lucida*[T], *R. pallens*[T], *R. tomentosa*[T]. Low Shrubs: *Elytropappus rhinocerotis* (d), *Eriocephalus africanus* var. *africanus* (d), *Oedera squarrosa* (d), *Pteronia incana* (d), *P. pallens* (d), *Senecio pinifolius* (d), *Euryops rehmannii*, *Maytenus oleoides*. Succulent Shrubs: *Ruschia caroli* (d), *Tylecodon paniculatus* (d), *Euphorbia burmannii*. Graminoids: *Ehrharta calycina* (d), *Ficinia ramosissima* (d), *Pentaschistis eriostoma* (d), *Ehrharta thunbergii*, *Ischyrolepis gaudichaudiana*.

Conservation Least threatened. Target 27%. About 30% protected in Langeberg-wes mountain catchment area. Only a small fraction has been transformed. The lowest-lying areas have been converted to vineyards and orchards, but slopes are generally too steep for further transformation. Erosion moderate.

Remark This unit is a virtually unknown vegetation type deserving scientific attention due to the isolated character of the granite pluton.

Reference N. Helme (unpublished data)

FRd 1 Nieuwoudtville-Roggeveld Dolerite Renosterveld

VT 28 Western Mountain Karoo (53%) (Acocks 1953). LR 56 Upland Succulent Karoo (62%) (Low & Rebelo 1996). Karroid Shrublands (73%), Mosaic of Dry Mountain Fynbos & Karroid Shrublands (27%) (Moll & Bossi 1983). BHU 75 Western Mountain Vygieveld (14%), BHU 35 Nieuwoudtville Inland Renosterveld (13%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Northern Cape Province: Dolerite ridges and surrounding plains east of the Bokkeveld Plateau, immediately east and northeast of Nieuwoudtville between the Doring River in the vicinity of Grasberg in the north and Schoongezicht in the south as well as similar small areas but collectively larger areas on the Roggeveld Plateau, between Middelpos and Sutherland. Altitude 740–1 500 m.

Vegetation & Landscape Features Ridges composed of rounded-block koppies and surrounding plains. The plains support species-rich herbland, seasonally dominated by geophytes and annuals, with an overstorey of nonsucculent shrubs, while the koppies supporting scattered shrubbery with low trees also occur in places. The vegetation of the dolerite plains is unique in being almost devoid of shrubs or perennial grasses. The koppies generally consist of cosmopolitan species derived from the adjacent karoo and renosterveld. Geophytes and annuals compose 90% of the cover and 80% of the species.

Geology & Soils Intrusive dolerites of the Jurassic Karoo Dolerite Suite giving rise to clay soils varying from fine-textured sands on the koppies to heavy red-clay vertisols on the lower slopes and plains. Land types mainly Fc, Ea, Da and Ib.

Climate MAP 140–530 mm (mean: 290 mm), peaking slightly from May to August. Mean daily maximum and minimum temperatures 30.3°C and 1.5°C for January and July, respectively. Frost incidence 10–50 days per year. See also climate diagram for FRd 1 Nieuwoudtville-Roggeveld Dolerite Renosterveld (Figure 4.117).

Important Taxa ([K]Koppies) Tall Shrubs: *Olea europaea* subsp. *africana*[K] (d), *Rhus undulata*[K] (d), *Montinia caryophyllacea*[K], *Melianthus comosus*. Low Shrubs: *Pentzia incana*[K], *Pteronia glauca*, *Stachys rugosa*[K]. Woody Climber: *Microloma sagittatum*. Woody Succulent Climber: *Zygophyllum foetidum*[K].

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Figure 4.120 FRd 1 Nieuwoudtville-Roggeveld Dolerite Renosterveld: Spring aspect with flowering *Bulbine latifolia* var. *doleritica* (Asphodelaceae) on Glen Lyon Farm near Nieuwoudtville (Northern Cape).

Semiparasitic Shrub: *Thesium lineatum*. Herbs: *Arctotis acaulis* (d), *Berkheya glabrata* (d), *Cotula nudicaulis* (d), *Senecio sisymbriifolius* (d), *Annesorhiza altiscapa, Hemimeris racemosa*[K], *Nemesia cheiranthus*, *Othonna auriculifolia*. Geophytic Herbs: *Brunsvigia bosmaniae* (d), *Oxalis callosa* (d), *Babiana spathacea, Gethyllis campanulata*[K], *Melasphaerula ramosa*, *Oxalis flava*, *Romulea austinii, Sparaxis elegans, Veltheimia capensis*[K]. Graminoids: *Ehrharta melicoides* (d), *Merxmuellera stricta* (d).

Biogeographically Important Taxa (both Roggeveld-Hantam endemics) Succulent Herb: *Quaqua arenicola* subsp. *pilifera*. Geophytic Herb: *Androcymbium pulchrum*.

Endemic Taxa ([K]Koppies, [W]Wetlands) Low Shrub: *Euryops rosulatus*. Herbs: *Emilia hantamensis* (d), *Heliophila collina* (d). Geophytic Herbs: *Bulbinella latifolia* subsp. *doleritica* (d), *Cyanella aquatica*[W], *Daubenya alba*, *D. capensis*, *D. stylosa*, *Diascia cardiosepala, Geissorhiza inaequalis*, *Hesperantha vaginata*, *Lachenalia neilii, Lapeirousia oreogena*, *Moraea fragrans*, *M. vespertina*[K], *Romulea monadelpha*, *Sparaxis pillansii*, *Trachyandra prolifera, Zantedeschia odorata*[K].

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Figure 4.121 FRd 2 Hantam Plateau Dolerite Renosterveld: Temporary wetlands on the top of the Hantam Plateau (Northern Cape) supporting clay dolerite renosterveld, dominated by *Bulbine latifolia* var. *latifolia* (Asphodelaceae).

Conservation Least threatened. Target 27%. Partly conserved in the Nieuwoudtville Flower Reserve as well as on Glenlyon Farm (by local farmer and conservationist Neil McGregor). About 4% transformed (mainly cultivation). The unit is under threat from overgrazing and invasion by alien grasses and herbs (*Avena fatua*, *Bromus pectinatus*, *Hordeum murinum*, *Lolium rigidum* and *Medicago polymorpha*) which are becoming dominant in many areas and suppressing the unique bulb flora. Erosion moderate and low.

Remarks Concentrations of number of geophytes near Nieuwoudtville have been verified as extremely high, reaching up to 25 000 bulbs per square metre (S.W. Todd & J.S. Donaldson, unpublished data). Together with FRs 2 Nieuwoudtville Shale Renosterveld, this as well as several SKv and SKt units form the core of the Roggeveld-Hantam Centre of Endemism (Van Wyk & Smith 2001), which contains the richest geophytic flora in the Cape flora. Geophytes constitute 40% of the local flora.

References Snijman & Perry (1987), Manning & Goldblatt (1997b), Van Wyk & Smith (2001), L. Mucina (unpublished data), S.W. Todd & J.S. Donaldson (unpublished data).

FRd 2 Hantam Plateau Dolerite Renosterveld

VT 28 Western Mountain Karoo (62%), VT 43 Mountain Renosterbosveld (26%) (Acocks 1953). LR 56 Upland Succulent Karoo (78%), LR 60 Escarpment Mountain Renosterveld (21%) (Low & Rebelo 1996). BHU Loeriesfontein Broken Veld (4%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Northern Cape Province: Plateau of the Hantamberg in the triangle between Sandkop, Downes and Driekuilspunt north of Calvinia as well as surrounding points such as Toringkop, Blomberg and to the south, Rebunieberg. Altitude 550–1 672 m at the (unnamed) highest point on the Hantam Plateau.

Vegetation & Landscape Features Plateau of tafelbergs supporting low shrubland with rich herblands containing a wealth of geophytes, especially in the more open, wetter or rocky habitats.

Geology & Soils Heavy, clayey soils and outcrops of intrusive dolerites (Jurassic Karoo Dolerite Suite) as well as (to a small extent) shales of the Ecca Group (Karoo Supergroup). Land type mainly Ib.

Climate MAP 160–440 mm (mean: 250 mm), peaking slightly from May to August. Mean daily maximum and minimum temperatures 31.1°C and 1.4°C for February and July, respectively. Frost incidence 10–40 days per year. See also climate diagram for FRd 2 Hantam Plateau Dolerite Renosterveld (Figure 4.117).

Important Taxa Tall Shrubs: *Cliffortia arborea*, *Diospyros austroafricana*. Low Shrubs: *Elytropappus rhinocerotis* (d), *Aptosimum spinescens*, *Argyrolobium collinum*, *Asparagus capensis* var. *capensis*, *Chrysocoma oblongifolia*, *Dimorphotheca cuneata*, *Eriocephalus africanus* var. *africanus*, *E. ericoides* subsp. *ericoides*, *E. spinescens*, *Euryops cuneatus*, *E. marlothii*, *E. trifidus*, *Felicia filifolia* subsp. *filifolia*, *F. macrorrhiza*, *Helichrysum hamulosum*, *H. lucilioides*, *Pteronia glauca*, *P. incana*, *Rosenia glandulosa*, *Stachys rugosa*, *Ursinia pilifera*. Succulent Shrubs: *Euphorbia mauritanica*, *E. stolonifera*. Semiparasitic Shrubs: *Thesium lineatum*, *T. namaquense*. Herbs: *Heliophila pendula*, *Senecio hastatus*. Geophytic Herbs: *Bulbinella nutans* subsp. *nutans*, *Geissorhiza heterostyla*, *Romulea diversiformis*, *R. luteoflora*, *Saniella occidentalis*. Succulent Herb: *Tetragonia robusta* var. *psiloptera*. Graminoids: *Chaetobromus involucratus* subsp. *dregeanus*, *Ehrharta calycina*, *E. capensis*, *E. melicoides*, *Merxmuellera dura*, *Schismus inermis*.

Endemic Taxa Geophytic Herbs: *Babiana praemorsa*, *Hesperantha hantamensis*, *H. oligantha*, *Moraea reflexa*, *Romulea hantamensis*.

Conservation Least threatened. Target 27%. Only 1% conserved (Akkerendam Nature Reserve near Calvinia). Only a very small portion has been transformed, but part of the area is exposed to grazing. Erosion moderate.

Remarks The Hantamberg is home to several endemic geophytes. These species are restricted to seasonally moist or inundated flats on the summit plateau. Disjunct links to the higher-

lying, wetter parts of the Roggeveld Escarpment include *Cliffortia arborea*, *Romulea diversiformis* and *Saniella occidentalis*. This unit forms part of the Roggeveld-Hantam Centre of Endemism (Van Wyk & Smith 2001).

References Manning & Goldblatt (1997b), Van Wyk & Smith (2001).

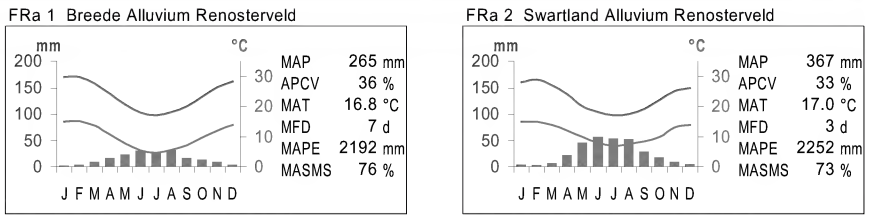

Figure 4.123 Climate diagrams of alluvium renosterveld units. Blue bars show the median monthly precipitation. The upper and lower red lines show the mean daily maximum and minimum temperature respectively. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days (days when screen temperature was below 0°C); MAPE: Mean Annual Potential Evaporation; MASMS: Mean Annual Soil Moisture Stress (% of days when evaporative demand was more than double the soil moisture supply).

9.2.3 *Alluvium Renosterveld*

Alluvium renosterveld is relatively rare, being confined to gravelly valley bottoms that usually contain either fynbos or riparian vegetation. It contains elements typical of fynbos (locally where sand predominates) or of succulent karoo—the latter especially in rocky and fire-safe habitats. This is an unusual azonal renosterveld straddling the ecotone between azonal saline (heavy soils) vegetation on one hand and AZa 2 Cape Lowland Alluvial Vegetation on the other. Only two types are recognised.

FRa 1 Breede Alluvium Renosterveld

VT 26 Karroid Broken Veld (90%) (Acocks 1953). LR 58 Little Succulent Karoo (69%), LR 61 Central Mountain Renosterveld (24%) (Low & Rebelo 1996). BHU 87 Robertson Broken Veld (69%), BHU 38 Ashton Inland Renosterveld (24%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Breede River, broad areas and narrow bands on valley bottomlands from Worcester to Ashton including the largest patch from Worcester to Nuy and Toontjiesrivier, and the belt in the vicinity of the Breede River also with many of its tributaries such as the Doringrivier south of Kwaggaskloof, Poesienetsrivier, Vinkrivier and Keisersrivier. Altitude 150–450 m.

Vegetation & Landscape Features Flat alluvial fans and valley bottoms supporting short grassy cupressoid-leaved shrubland usually dominated by renosterbos.

Geology & Soils Fine loamy sand with high gravel and cobble contents of alluvial fans and river terraces, overlying a variety of rocks from the Cape and Karoo Supergroups as well as the Uitenhage Group. Glenrosa and Mispah forms and soils with prismacutanic and/or pedocutanic diagnostic horizons are dominant. Land types mainly Fc, Db, Da, Ae and Ia.

Climate MAP 170–470 mm (mean: 265 mm), peaking slightly from July to August. Mean daily maximum and minimum temperatures 29.8°C and 4.7°C for February and July, respectively. Frost incidence 4–10 days per year. See also climate diagram for FRa 1 Breede Alluvium Renosterveld (Figure 4.123).

Important Taxa Tall Shrubs: *Montinia caryophyllacea*, *Rhus lucida*. Low Shrubs: *Amphithalea spinosa*, *Aspalathus candicans*, *A. spinosa* subsp. *spinosa*, *Athanasia trifurcata*, *Cliffortia ruscifolia*, *Elytropappus rhinocerotis*, *Diosma passerinoides*, *Helichrysum incarnatum*, *Oedera imbricata*, *O. squarrosa*, *Pentzia incana*. Succulent Shrub: *Ruschia caroli* (d). Herbs: *Corymbium glabrum*, *Senecio erysimoides*. Geophytic Herbs: *Gladiolus permeabilis* subsp. *permeabilis*, *Moraea gawleri*. Succulent Herb: *Crassula expansa* subsp. *expansa*. Graminoids: *Willdenowia incurvata* (d), *Cynodon dactylon*, *Ehrharta longiflora*, *E. villosa* var. *villosa*, *Eragrostis curvula*, *Themeda triandra*.

Endemic Taxon Geophytic Herb: *Ixia collina*.

Conservation Endangered. Target 27%. Small patches conserved in the Vrolijkheid and Riviersonderend Nature Reserves. Some 57% already transformed (cultivation, mainly vineyards). Alien species of *Acacia* occur locally at low densities. Erosion generally moderate and very low, but also high in some places.

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Figure 4.122 FRa 1 Breede Alluvium Renosterveld: Disturbed renosterveld shrubland with *Elytropappus rhinocerotis* and *Galenia africana* at the bottom of the Breede River Valley near Worcester (Western Cape).

Remark Breede Alluvium Renosterveld becomes replaced by AZi 8 Muscadel Riviere on heavier and more saline soils in the eastern parts of the Breede River Valley.

References Grobler & Marais (1967), C. Boucher (unpublished data).

FRa 2 Swartland Alluvium Renosterveld

VT 47 Coastal Macchia (63%), VT 46 Coastal Renosterbosveld (37%) (Acocks 1953). LR 68 Sand Plain Fynbos (79%), LR 62 West Coast Renosterveld (21%) (Low & Rebelo 1996). Sand Plain Fynbos (22%) (Moll & Bossi 1983). BHU 11 Hopefield Sand Plain Fynbos (67%), BHU 31 Swartland Coast Renosterveld (31%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Narrow belts in the southern Swartland encompassed by Klipheuwel, Malmesbury,

Moorreesburg and Darling along the Groen and Diep Rivers. Altitude 40–150 m.

Vegetation & Landscape Features Riverine plains and bottomlands. Open, low, short cupressoid and low to moderately tall, grassy shrubland, dominated by renosterbos.

Geology & Soils Mainly fine silty and sandy alluvial sediments, mainly derived from Cape Granite. Soils with prismacutanic and/or pedocutanic diagnostic horizons are dominant. Land types mainly Db.

Climate MAP 300–490 mm (mean: 370 mm), peaking from May to August. Mists common in winter. Mean daily maximum and minimum temperatures 28.8°C and 7.0°C for February and July, respectively. Frost incidence about 3 days per year. See also climate diagram for FRa 2 Swartland Alluvium Renosterveld (Figure 4.123).

Important Taxa ([W]Wetlands) Tall Shrubs: *Psoralea aphylla* (d), *Rhus angustifolia* (d), *R. laevigata*. Low Shrubs: *Cliffortia ferruginea* (d), *Galenia secunda* (d), *Aspalathus spinosa* subsp. *spinosa*, *Asparagus capensis* var. *capensis*, *Cliffortia juniperina*, *Diospyros austro-africana*, *Eriocephalus africanus* var. *africanus*, *Galenia africana*, *Oftia africana*, *Stoebe plumosa*, *Xiphotheca lanceolata*. Herbs: *Adenogramma glomerata*, *Berkheya rigida*, *Dischisma ciliatum* subsp. *ciliatum*, *Echiostachys spicatus*. Geophytic Herbs: *Pteridium aquilinum* (d), *Zantedeschia aethiopica*[W] (d), *Ornithogalum thyrsoides*[W], *Oxalis goniorrhiza*. Graminoids: *Cynodon dactylon* (d), *Ficinia brevifolia* (d), *Sporobolus virginicus* (d), *Calopsis paniculata*, *Elegia tectorum*, *Isolepis antarctica*[W], *I. trachysperma*[W], *Juncus capensis*[W], *Pycreus polystachyos*[W], *Tribolium echinatum*.

Conservation Vulnerable. Target 26%. None conserved in statutory or private conservation areas. Total transformed 40% (mainly cultivation). Infestation by alien woody species is serious and involves various species of *Acacia*, *Eucalyptus*, *Pinus* and *Prosopis*. Erosion low and very low.

Remarks We presume that this vegetation type might have been much more extensive in the past and might have had a greater tree component along the river courses. On heavier and more saline soils this vegetation becomes replaced on alluvia of (often intermittent) West Coast rivers by azonal inland saline vegetation of the AZi 9 Cape Inland Salt Pans and AZa 2 Cape Lowland Alluvial Vegetation.

References Boucher (1983, 1987, 1999b).

9.2.4 Silcrete and Limestone Renosterveld

These miscellaneous renosterveld types tend to be transitional to fynbos. They are unrelated to one another and share species with their neighbouring types. All are extremely poorly known and given their peculiar substrates and circumstances, may well yield new and endemic species. Together they comprise less than 3% of the area of renosterveld vegetation.

FRc 1 Swartland Silcrete Renosterveld

VT 46 Coastal Renosterbosveld (92%) (Acocks 1953). LR 62 West Coast Renosterveld (76%), LR 68 Sand Plain Fynbos (24%) (Low & Rebelo 1996). BHU 31 Swartland Coast Renosterveld (63%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: A highly fragmented type, scattered in the form of small patches throughout the Swartland from near Firgrove and Kuils River in the south to Eendekuil to Piketberg in the north. Mostly embedded within FRs 9 Swartland Shale Renosterveld followed by FRg 2 Swartland Granite Renosterveld. The largest patch is at Oupas between Moorreesburg and Mamre. Altitude 40–220 m.

Vegetation & Landscape Features Moderately undulating lowlands, often on elevated areas. An open, low, cupressoid- and small-leaved, low to moderately tall shrubland with many succulents, dominated by renosterbos.

Geology & Soils Remnants of silcrete layers over Malmesbury Group Shale and Cape Granite. Soils with prismacutanic and/or pedocutanic diagnostic horizons or plinthic catena are dominant. Land types mainly Db, Ca and Fc.

Climate MAP 250–650 mm (mean: 425 mm), peaking from May to August. Mists common in winter. Mean daily maximum and minimum temperatures 28.7°C and 6.8°C for February and July, respectively. Frost incidence 3 or 4 days per year. See also climate diagram for FRc 1 Swartland Silcrete Renosterveld (Figure 4.124).

Important Taxa Tall Shrubs: *Montinia caryophyllacea*, *Protea burchellii*. Low Shrubs: *Erica muscosa* (d), *Agathosma marifolia*, *Anthospermum spathulatum* subsp. *tulbaghense*, *Elytropappus rhinocerotis*, *Erica brachysepala*, *Eriocephalus africanus* var. *africanus*, *Helichrysum teretifolium*, *Lobostemon fruticosus*, *Muraltia macropetala*, *M. origanoides*, *M. trinervia*. Succulent Shrubs: *Drosanthemum asperulum*, *Euphorbia burmannii*, *Lampranthus filicaulis*. Geophytic Herbs: *Geissorhiza purpureolutea*, *G. setacea*, *Lachenalia longibracteata*, *L. pallida*. Succulent Herb: *Psilocaulon parviflorum*. Graminoids: *Ehrharta calycina*, *E. thunbergii*, *Ischyrolepis capensis*.

Endemic Taxa Low Shrub: *Marasmodes oligocephala*. Succulent Shrubs: *Lampranthus dilutus*, *Ruschia serrulata*. Geophytic Herb: *Babiana longiflora*.

Conservation Critically endangered and the conservation target of 26% remains unattainable due to total transformation of 90% (mainly turned into agricultural land). Small patches

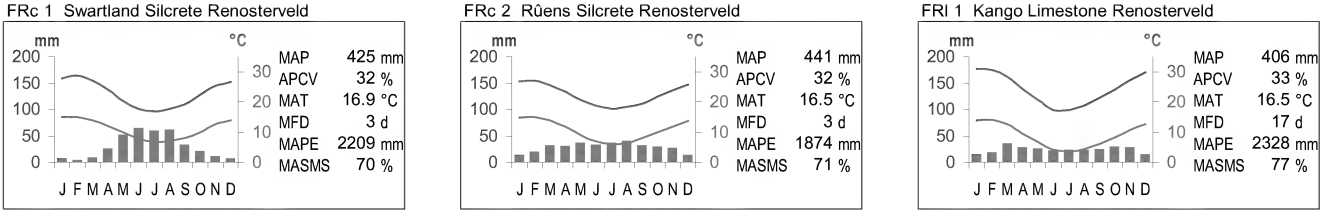


Figure 4.124 Climate diagrams of silcrete and limestone renosterveld units. Blue bars show the median monthly precipitation. The upper and lower red lines show the mean daily maximum and minimum temperature respectively. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days (days when screen temperature was below 0°C); MAPE: Mean Annual Potential Evaporation; MASMS: Mean Annual Soil Moisture Stress (% of days when evaporative demand was more than double the soil moisture supply).

L. Mucina

Figure 4.125 FRc 1 Swartland Silcrete Renosterveld: Ferricrete patches with rich geophytic spring flora (*Ornithogalum*, *Lachenalia*, *Micranthus alopecuroides*) and scattered solitary shrubs of *Leucadendron stellare* near the Boland Agricultural College in Wellington (Western Cape).

remnant African surface. These isolated habitats support open, low, cupressoid and small-leaved, low to moderately tall shrubland characterised by many succulents and usually dominated by renosterbos.

Geology & Soils Shallow soils with silcrete caps over deep pink and orange shales of the Bokkeveld Group, on hill tops. Occasionally they also occur on ferricrete or in quartz patches. Soils are prismacutanic and pedocutanic. Land types mainly Db, Fc and Fb.

Climate MAP 280–770 mm (mean: 440 mm), relatively even throughout the year with a slight low from December to February. Mean daily maximum and minimum temperatures 26.9°C and 6.0°C for January–February and July, respectively. Frost incidence about 3 days per year. See also climate diagram for FRc 2 Rûens Silcrete Renosterveld (Figure 4.124).

(about 1%) are statutorily conserved in the Pella Research Site, and additionally in Paardenberg and Elandsberg. Remaining patches undergo transformation by overgrazing, fire protection, and spraying with herbicides and insecticides. Alien *Acacia saligna*, *A. mearnsii*, *Prosopis* and *Eucalyptus* are also a problem in places. Erosion very low and low.

Remarks This unit has strong fynbos elements. It has been heavily impacted by road building and agriculture, and the remaining remnants are usually transformed by overgrazing and bush-cutting so that their original floras are unknown.

References Acocks (1935), Boucher (1987), Walton (2006), N. Helme (unpublished data).

FRc 2 Rûens Silcrete Renosterveld

VT 46 Coastal Renosterbosveld (80%) (Acocks 1953). LR 63 South and Southwest Coast Renosterveld (100%) (Low & Rebelo 1996). BHU 34 Riversdale Coast Renosterveld (75%), BHU 33 Overberg Coast Renosterveld (19%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

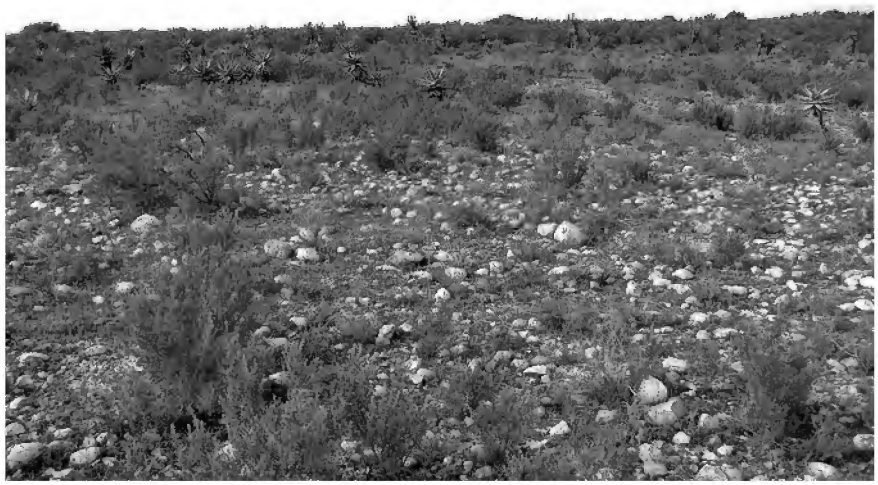
Distribution Western Cape Province: Rûens coastal forelands from Riviersonderend to Riversdale, with isolated outliers westwards to Bot River, but only really common within FRs 13 Eastern Rûens Shale Renosterveld. A highly fragmented unit by nature of its tendency to occur on the well-dissected, old African surface. Particularly common along the lower Breede River south of Buffeljagsrivier to Malgas and further downstream, and also south of Heidelberg and Riversdale (particularly in the Brakrivier area). Altitude 50–350 m.

Vegetation & Landscape Features Highly fragmented patches on the summits and highlands of undulating hills and plains, larger patches often associated with drainage systems. In contrast to the isolated and rare occurrence of silcrete renosterveld on the West Coast, on the South Coast this is a major landscape feature on the uplands, where it forms a

Important Taxa Tall Shrub: *Rhus lucida*. Low Shrubs: *Cymbopappus adenosolen* (d), *Elytropappus rhinocerotis* (d), *Erica karooica* (d), *Hermannia saccifera* (d), *Oedera squarrosa* (d), *Relhania garnotii* (d), *Agathosma foetidissima*, *Euchaetis longicornis*, *Macledium spinosum*, *Polhillia pallens*, *Selago corymbosa*, *Sutera aethiopica*. Succulent Shrubs: *Drosanthemum asperulum* (d), *Crassula subulata* var. *subulata*. Herb: *Tripteris tomentosa* (d). Geophytic Herbs: *Bulbinella barkeriae*, *Tritoniopsis flexuosa*. Succulent Herbs: *Psilocaulon parviflorum*, *Stapeliopsis breviloba*. Graminoids: *Cymbopogon pospischilii* (d), *Ficinia oligantha* (d), *Merxmuellera stricta* (d), *Eragrostis curvula*, *Merxmuellera disticha*, *Themeda triandra*.

Endemic Taxa Low Shrubs: *Erica venustiflora* subsp. *glandulosa* (d), *Liparia striata*, *Polhillia canescens*. Succulent Shrubs: *Acrodon deminutus*, *Antimima* sp. nov. (*N. Helme 2101* NBG), *Brownanthus fraternus*, *Drosanthemum quadratum*, *Gibbaeum esterhuyseniae*, *G. haagei*. Succulent Herbs: *Haworthia variegata* var. *hemicrypta*, *Stapelia divaricata*, *Stapeliopsis saxatilis* subsp. *stayneri*.

Conservation Critically endangered. The target of 27% remains unattainable since 78% of the area has already been



J.P. Groenewald

Figure 4.126 FRc 2 Rûens Silcrete Renosterveld: Sparse renosterveld shrubland on silcrete outcrops with *Cliffortia ruscifolia* and *Aloe ferox* (in the background) on the Farm Kekkel en Kraai near Swellendam (Western Cape).

transformed for intensive agricultural land. Very small portion (less than 1%) statutorily conserved in the Werner Frehse Nature Reserve (near Riversdale). Alien *Acacia cyclops* scattered over parts of the area. Erosion moderate and low.

Remarks A number of regional taxa are shared with the Rûens renosterveld units. Some of the succulent elements (*Drosanthemum*, *Gibbaeum*) provide a biogeographical link to SKv 7 Robertson Karoo.

References Schmiedel (2002), Von Hase et al. (2003), Schmiedel & Mucina (2006).

FRl 1 Kango Limestone Renosterveld

VT 25 Succulent Mountain Scrub (Spekboomveld) (65%), VT 43 Mountain Renosterveld (27%) (Acocks 1953). South Coast Renosterveld (58%) (Moll & Bossi 1983). LR 63 South and South-west Coast Renosterveld (67%), LR 8 Spekboom Succulent Thicket (26%) (Low & Rebelo 1996). BHU 43 Kango Inland Renosterveld (68%), BHU 97 Spekboom Xeric Succulent Thicket (27%) (Cowling et al. 1999b, Cowling & Heijnis 2001). STEP Meiringspoort Fynbos Thicket (20%), STEP Mons Ruber Fynbos Thicket (16%), STEP Cango Renoster Thicket (4%) (Vlok & Euston-Brown 2002).

Distribution Western Cape Province: Northeastern regions of the Little Karoo south of the Groot Swartberg, from near Gamkapoort, north of Calitzdorp eastwards including Matjiesrivier and the Cango Caves area, with another band extending from upper Schoemanspoort and De Rust to north of the Stompdrift Dam. Altitude 450–950 m.

Vegetation & Landscape Features Low mountains and steep hills, supporting low, medium dense graminoid and medium to tall, dense, cupressoid-leaved shrubland, dominated by renosterbos and *Dodonaea*. The upper and wetter slopes are dominated by *Dodonaea viscosa* var. *angustifolia*, which although it is the visual signature of this type, extends onto neighbouring fynbos types. Frequent burning leads to a *Themeda* grassland. The early post-fire stages are characterised by a high diversity of herbaceous species—on limestone *Hermannia holosericea* is dominant in the early seral stages. A feature of the type is the marked lack of geophytes (only *Hypoxis villosa*).

Geology & Soils Clays and loams derived from the Cango Caves Group shales and limestone of the Namibian Erathem; in the south the area overlies clastic sediments of the Mesozoic Uitenhage Group; soils of Glenrosa and Mispah forms or red-yellow apedal soils dominant. Land types mainly Ib, Fc and Ag.

Climate MAP 200–720 mm (mean: 405 mm), peaking in March but otherwise even with a slight low from December to February. Mean daily maximum and minimum temperatures 31.0°C and 3.5°C for January and July, respectively. Frost incidence 10–20 days per year. See also climate diagram for FRl 1 Kango Limestone Renosterveld (Figure 4.124).

Important Taxa (TCape thickets) Small Tree: *Acacia karroo*. Succulent Tree: *Aloe ferox*. Tall Shrubs: *Cussonia paniculata* subsp. *paniculata*T (d), *C. spicata*T (d), *Dodonaea viscosa* var. *angustifolia* (d), *Euclea undulata*T (d), *Rhus laevigata*T (d), *R. undulata*T (d), *Anginon difforme*, *Maytenus heterophylla*T, *Olea europaea* subsp. *africana*T, *Pterocelastrus tricuspidatus*T. Low Shrubs: *Elytropappus rhinocerotis* (d), *Hermannia holosericea* (d), *Carissa bispinosa* subsp. *bispinosa*. Succulent Shrubs: *Cotyledon orbiculata* var. *orbiculata*, *Crassula arborescens*, *Euphorbia heptagona*, *E. mauritanica*, *Portulacaria afra*. Semiparasitic Shrub: *Osyris compressa*. Herb: *Sutera patriotica*. Geophytic Herbs: *Hypoxis villosa*, *Romulea austinii*. Succulent Herb: *Senecio ficoides*. Graminoids: *Hyparrhenia hirta* (d), *Eustachys paspaloides*, *Themeda triandra*.

Endemic Taxa Herb: *Phyllopodium dolomiticum*. Geophytic Herb: *Ornithogalum sardienii*. Succulent Herbs: *Haworthia blackburniae* var. *graminifolia*, *H. scabra* var. *lateganiae*, *H. scabra* var. *morrisiae*, *H. scabra* var. *starkiana*.

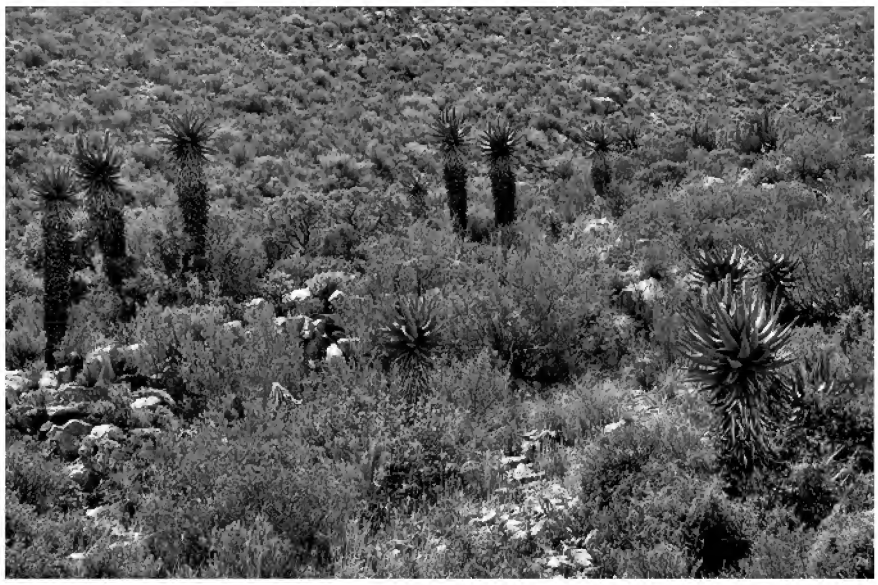
Conservation Least threatened. Target 29%. Very small portion conserved in Groot Swartberg and Rietvlei. Only 14% transformed (cultivation), but almost exclusively on the valley bottoms. Erosion low and very low.

Remarks Although centred on limestone, this unit also occurs on other geological substrates occupied by renosterveld in the Cango Valley of the Swartberg foothills. Compared to the richness of other limestone areas in the Cape flora, this unit is unusually poor—probably because it is poorly explored. In fire-protected sites such as steep rocky slopes and ravines this renosterveld is replaced by dense succulent thickets of AT 2 Gamka Thicket.

References Moffett & Deacon (1977), Vlok & Euston-Brown (2002).

9.3 Western Strandveld

Western Strandveld currently consists of nine vegetation units that basically reflect phytogeographical (hence climatic to an extent) and geological patterns. Six of the units are found on the dry West Coast. Those occurring on and around Langebaan Peninsula (especially on granite, limestone) are floristically diverse and possibly also evolutionary older as they contain a high number of local endemics. FS 1 Lambert's Bay Strandveld and FS 5 Langebaan Dune Strandveld are rich in succulent elements. The classification of the remaining three strandveld types reflects floristic gradients between the western and eastern portions of the South Coast. More data are needed to judge the



L. Mucina

Figure 4.127 FRl 1 Kango Limestone Renosterveld: Renosterveld shrubland dominated by *Dodonaea viscosa* var. *angustifolia* with *Aloe ferox* on Cango Caves Group limestones near the entrance to Meiringspoort at De Rust in the Little Karoo (Western Cape).

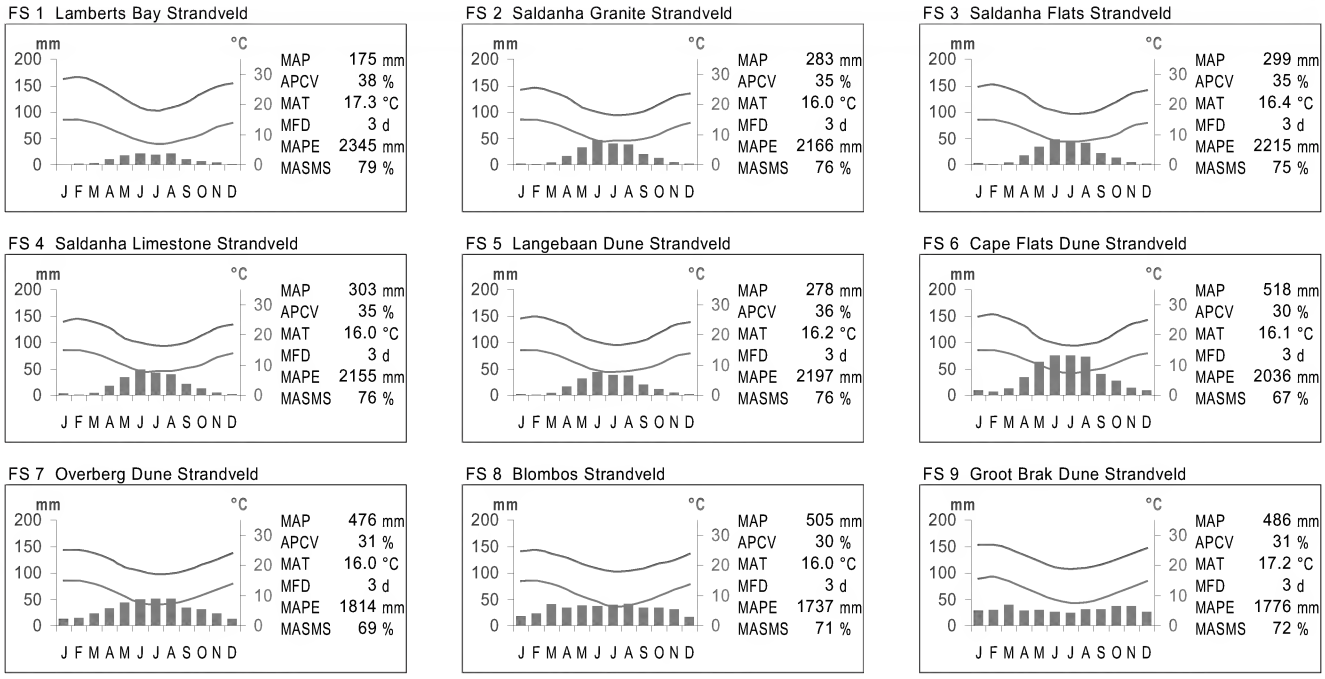


Figure 4.128 Climate diagrams of Western Strandveld units. Blue bars show the median monthly precipitation. The upper and lower red lines show the mean daily maximum and minimum temperature respectively. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days (days when screen temperature was below 0°C); MAPE: Mean Annual Potential Evaporation; MASMS: Mean Annual Soil Moisture Stress (% of days when evaporative demand was more than double the soil moisture supply).

role of geology in the differentiation of the Western Strandveld types, especially along those parts of the South Coast that do not have limestone geology. Basic ecological characteristics of the Western Strandveld are discussed in Section 3.3.

FS 1 Lambert's Bay Strandveld

VT 34 Strandveld of West Coast (100%) (Acocks 1953). LR 55 Strandveld Succulent Karoo (57%) (Low & Rebelo 1996). West Coast Strandveld (49%), Sand Plain Fynbos (39%) (Moll & Bossi 1983). BHU 83 Lambert's Bay Strandveld (57%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Broad coastal strip between Donkin Bay (north of Lambert's Bay) and Elands Bay (Verlorenvlei), penetrating deeply inland north of and along the Jakkals and Langvlei Rivers. Altitude 20–180 m.

Vegetation & Landscape Features Series of old dunes and slightly undulating, consolidated sand-dune fields supporting mixed, 1.2–1.5 m tall, dense shrubland composed of evergreen, sclerophyllous and fleshy, drought-deciduous-leaved shrubs, with a dense understorey of low (0.2–0.5 m), unpalatable, succulent shrubs. Perennial herbs and annuals are dominant in degraded areas.

Geology & Soils Table Mountain Group sandstones form a rocky coastline and occur as sporadic outcrops throughout the area. The substrate is mainly deep, Tertiary to Quaternary, white to pale red, calcareous, aeolian, sandy to sandy loam soil of the hillocky veld. Local white sand of Pleistocene origin forms unstable blow-out dunes north of the mouths of the Verlorenvlei River at Elands Bay and the Jakkals River at Lambert's Bay. Recent calcareous sands of marine origin also line the coastal strip. Dominant land types Hb and Ha.

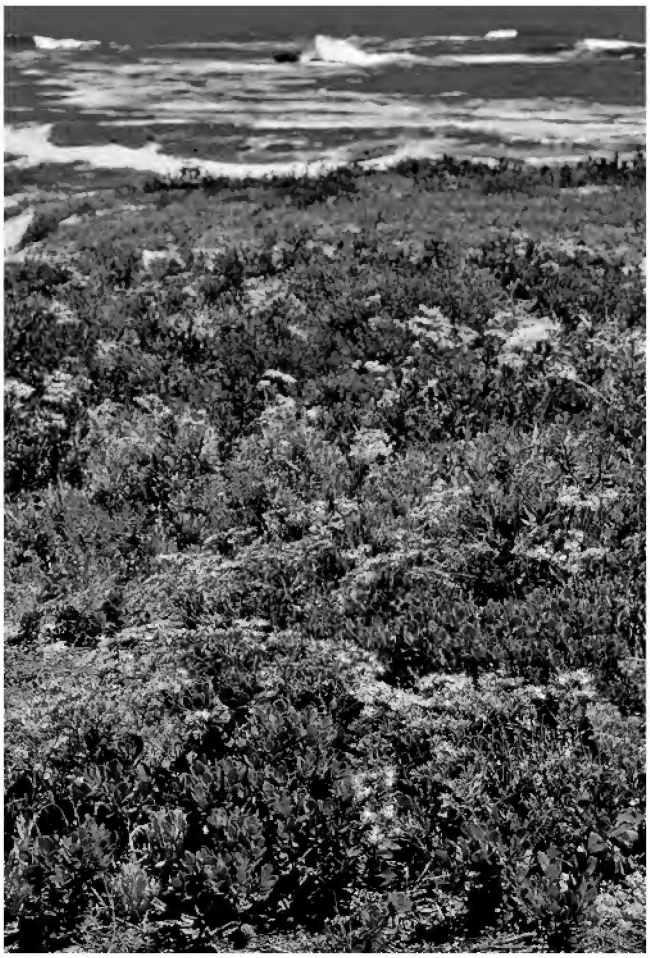
Climate Mainly cyclonic annual rainfall varying from approximately 125 mm in the north to 200 mm in the south (overall MAP: 175 mm), occurring on average over six days in winter. Fog and dew contribute to the moisture in summer and autumn. Mean daily maximum and minimum temperatures 29.1°C and 7.0°C for February and July, respectively. Frost and hail are rare phenomena. The winds tend to be strong southerly in summer and northerly in winter. Hot, dry, desiccating offshore winds occur in both winter and summer. Salt-laden on-shore winds stunt shrubs along the coast. See also climate diagram for FS 1 Lambert's Bay Strandveld (Figure 4.128).

Important Taxa Tall Shrubs: *Euclea racemosa* subsp. *racemosa*, *Rhus undulata*. Low Shrubs: *Chrysanthemoides monilifera*, *Eriocephalus racemosus*, *Hebenstretia cordata*, *Lebeckia multiflora*, *Salvia lanceolata*. Succulent Shrubs: *Euphorbia mauritanica* (d), *Zygophyllum morgsana* (d), *Cotyledon orbiculata* var. *dactylopsis*, *C. orbiculata* var. *spuria*, *Didelta carnosa*, *Euphorbia rhombifolia*, *Lycium tetrandrum*, *Manochlamys albicans*, *Othonna carnosa*, *Pelargonium carnosum*, *Ruschia caroli*, *R. cymosa*, *Tetragonia decumbens*, *T. fruticosa*, *T. namaquensis*, *T. spicata*. Herbs: *Oncosiphon suffruticosum* (d), *Senecio arenarius* (d), *Helichrysum litorale*, *Oncosiphon piluliferum*, *Wahlenbergia annularis*, *Zaluzianskya villosa*. Geophytic Herbs: *Lachenalia rubida*, *Trachyandra divaricata*. Succulent Herbs: *Carpobrotus edulis*, *Crassula expansa* subsp. *expansa*, *Mesembryanthemum guerichianum*. Herbaceous Climber: *Cynanchum africanum*. Graminoids: *Chaetobromus involucratus* subsp. *dregeanus*, *Ehrharta calycina*, *E. villosa* var. *villosa*, *Willdenowia incurvata*.

Biogeographically Important Taxa (all West Coast endemics) Low Shrubs: *Afrolimon peregrinum* (d), *Pteronia onobromoides* (d), *Asparagus capensis* var. *litoralis*, *Lycium strandveldense*. Succulent Shrubs: *Euphorbia caput-medusae*, *Pelargonium gibbosum*. Herbs: *Amellus asteroides*, *Arctotis stoechadifolia*, *Grielum grandiflorum*. Geophytic Herbs: *Babiana thunbergii*, *Ferraria densepunctulata*. Graminoid: *Cladoraphis cyperoides*.

Endemic Taxa Herb: *Felicia josephinae*. Succulent Herb: *Conophytum obcordellum* subsp. *rolfii*.

Conservation Vulnerable. Target 24%. Only about 1.5% statutorily conserved in the Elandsbaai Nature Reserve and a further about 7% in private conservation areas such as Soopjeshoogte,



L. Mucina

Figure 4.129 FS 1 Lambert's Bay Strandveld: Low strandveld shrubland with dominant *Afrolimon peregrinum* (Plumbaginaceae) and abundant succulents (*Amphibolia, Conicosia, Euphorbia, Mesembryanthemum, Ruschia*) near Lambert's Bay (Western Cape).

Donkins Bay, Zeven Puts and Doorspring Nature Reserves. About a quarter transformed for cultivation. This vegetation has been exposed to 2 000 years of stock farming. *Acacia cyclops* and *A. saligna* are serious invading aliens. Erosion generally very low.

Remarks Increased occurrence of Succulent Karoo elements underlines the similarity of this vegetation unit to SKs 7 Namaqualand Strandveld. The white calcareous dunes lining the Atlantic seaboard support vegetation, with close affinity to FS 5 Langebaan Dune Strandveld occurring further south.

References Boucher (1982), Liengme (1987), Boucher & Le Roux (1993), Boucher (1998d, f), Venter & Venter (2003), Downing & Van der Merwe (undated).

FS 2 Saldanha Granite Strandveld

VT 46 Coastal Renosterbosveld (51%) (Acocks 1953). *Galenia–Senecio* Hillside Closed Dwarf Shrubland, *Ehrharta–Maurocenia* Hillside Dense Shrubland (Boucher & Jarman 1977). West Coast Strandveld p.p. (Boucher 1983). LR 4 Dune Thicket (99%) (Low & Rebelo 1996). BHU 4 Langebaan Fynbos/Thicket Mosaic (99%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: On the West Coast, granite domes from Vredenburg to St Helena Bay and many points along the coast including Paternoster and Saldanha's North Head; also around Langebaan town and at Postberg on the Langebaan Peninsula. Altitude 0–180 m.

Vegetation & Landscape Features Rounded forms of granite sheets and smooth forms at their feet dominate the landscapes of this vegetation unit. Low to medium shrubland, containing some succulent elements, alternates with grassy and herb-rich spots supporting a rich geophyte flora.

Geology & Soils Deep, coarse sandy to loamy soils derived from the Vredenburg Batholith in the north and the Saldanha Batholith in the south (both of the Cape Granite Suite). Dominant land type Ab, followed by Fc.

Climate Mainly cyclonic annual rainfall varying from approximately 250 mm in the north to 350 mm in the south, almost exclusively in winter. Mean daily maximum and minimum temperatures 25.4°C and 7.9°C for February and July, respectively. Advective sea fog and dew contribute significantly to the moisture in summer and autumn. Frost rare. Winds tend to be strong northwesterly in winter and southerly in summer. See also climate diagram for FS 2 Saldanha Granite Strandveld (Figure 4.128).

Important Taxa Tall Shrubs: *Euclea racemosa* subsp. *racemosa*, *Passerina corymbosa*, *Rhus glauca*. Low Shrubs: *Pteronia divaricata* (d), *Agathosma bifida*, *Eriocephalus africanus* var. *africanus*, *Exomis microphylla*, *Otholobium hirtum*, *Polygala myrtifolia*, *Pterocelastrus tricuspidatus*, *Putterlickia pyracantha*. Succulent Shrubs: *Aloe perfoliata*, *Drosanthemum floribundum*, *Euphorbia mauritanica*, *Lycium tetrandrum*, *Othonna floribunda*, *Tetragonia fruticosa*, *T. spicata*, *Tylecodon paniculatus*, *Zygophyllum morgsana*. Woody Climber: *Cissampelos capensis*. Semiparasitic Shrub: *Osyris compressa*. Herbs: *Dimorphotheca pluvialis* (d), *Oncosiphon suffruticosum* (d), *Adenogramma glomerata*, *Nemesia versicolor*, *Senecio arenarius*, *Ursinia anthemoides* subsp. *anthemoides*. Geophytic Herbs: *Amaryllis belladonna*, *Chasmanthe floribunda*, *Freesia viridis*, *Geissorhiza monanthos*, *Lachenalia pustulata*, *Melasphaerula ramosa*, *Romulea hirsuta*. Succulent Herb: *Dorotheanthus bellidiformis* (d). Graminoids: *Chaetobromus involucratus* subsp. *dregeanus*, *C. involucratus* subsp. *involucratus*, *Cynodon dactylon*, *Ehrharta*

J.C. Manning

Figure 4.130 FS 2 Saldanha Granite Strandveld: Succulent-rich shrublands on steep slopes of a granite koppie near Langebaan (Western Cape) with *Aloe mitriformis*, *Othonna arborescens* and *Cheiridopsis rostrata*.

K. Phillips

Figure 4.131 FS 2 Saldanha Granite Strandveld: Spectacular spring display of *Dimorphotheca pluvialis* (Asteraceae) on granite in the Postberg Reserve within the West Coast National Park near Langebaan (Western Cape).

calycina, *E. villosa* var. *villosa*, *Festuca scabra*, *Tribolium echinatum*, *Willdenowia incurvata*.

Biogeographically Important Taxa (all West Coast endemics) Low Shrub: *Afrolimon peregrinum* (d). Herb: *Cotula duckittiae* (d). Geophytic Herbs: *Polyxena corymbosa*, *Sparaxis parviflora*. Succulent Herb: *Quaqua incarnata* subsp. *incarnata*.

Endemic Taxa Succulent Shrubs: *Lampranthus aureus*, *Oscularia steenbergensis*, *O. vredenburgensis*, *Ruschia langebaanensis*. Geophytic Herbs: *Lachenalia mathewsii* (d), *Hesperantha saldanhae*, *Lachenalia viridiflora*, *Moraea loubseri* (extinct in the wild), *Ornithogalum rupestre*, *Oxalis burtoniae*, *Pauridia longituba*, *Polyxena paucifolia*, *Romulea saldanhensis*, *Strumaria chaplinii*, *Watsonia hysterantha*.

Conservation Endangered. Target 24%. Almost 10% statutorily conserved in the West Coast National Park, SAS Saldanha and Columbine Nature Reserves, and a small portion in private reserves such as West Point, Groot Paternoster and Swartriet. About 70% transformed for cultivation or by urban development. This vegetation type is regularly utilised for grazing. Australian *Acacia saligna*, *A. cyclops* and *A. baileyana* are causing serious infestations in many places. Coastal development is a further threat to this vegetation type. Erosion low and very low.

Remarks The most northerly distribution of *Erica tristis* trees are found at Langebaan, with a gap of at least 100 km to the nearest other plants commonly found in rocky coastal habitats between the Cape Peninsula and Gansbaai.

References Boucher & Jarman (1977), Boucher (1982, 1983, 1987), Boucher & Rode (1999).

FS 3 Saldanha Flats Strandveld

VT 47 Coastal Macchia (64%) (Acocks 1953). West Coast Strandveld p.p. (Boucher 1983). LR 4 Dune Thicket (84%) (Low & Rebelo 1996). BHU 4 Langebaan Fynbos/Thicket Mosaic (78%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Extensive coastal flats from St Helena Bay and the southern banks of the Great Berg River near its mouth in the north to Saldanha and Langebaan in the south, with the southernmost extension at the coast near Yzerfontein and Rietduin. Altitude 0–120 m.

Vegetation & Landscape Features Sclerophyllous shrublands built of a sparse emergent and moderately tall shrub layer, with an open succulent shrub layer forming the undergrowth. With conspicuous displays of geophytes and annual herbaceous flora in spring.

Geology & Soils The main geology is shallow calcareous sand over a fossiliferous Pleistocene limestone hardpan layer along an old marine terrace. The hardpan of the Sandveld Group is exposed in places while farmers often rip the hardpan and accumulate rock piles in cultivated fields. The Sandveld Group overlies the Cape Granites as well as the Malmesbury Group metasediments into which the granites intruded. Dominant land type Hb (almost 50%), followed by Db and Ha.

Climate Mainly cyclonic rainfall varying from approximately 250 mm in the north to 380 mm in the south (overall MAP: 300 mm), almost exclusively in winter. Mean daily maximum and minimum temperatures 26.6°C and 7.9°C for February and July, respectively. Mean monthly maximum and minimum temperatures for Langebaanweg 36.5°C and 2.2°C for January/February and July/August, respectively. Advective sea fog and dew contribute to the moisture balance in summer and autumn. Frost infrequent. Strong southeasterly winds typical of the summer period, northerly winds more frequent in the winter months, especially between May and August. See also climate diagram for FS 3 Saldanha Flats Strandveld (Figure 4.128).

Important Taxa Tall Shrubs: *Euclea racemosa* subsp. *racemosa* (d), *Nylandtia spinosa*, *Rhus glauca*. Low Shrubs: *Aspalathus lotoides* subsp. *lagopus*, *Clutia daphnoides*, *Euryops linifolius*,

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Figure 4.132 FS 3 Saldanha Flats Strandveld: Strandveld on deep calcareous sands with *Afrolimon capense* (Plumbaginaceae) and *Tylecodon wallichii* (Crassulaceae) near Saldanha (Western Cape).

Exomis microphylla, *Hermannia pinnata*, *Lebeckia sericea*, *Leysera gnaphalodes*, *Nenax hirta* subsp. *calciphila*, *Pterocelastrus tricuspidatus*, *Pteronia divaricata*, *P. ovalifolia*, *P. uncinata*. Succulent Shrubs: *Euphorbia mauritanica*, *Ruschia macowanii*, *Tetragonia decumbens*, *T. fruticosa*, *Zygophyllum cordifolium*, *Z. morgsana*. Herbs: *Dimorphotheca pluvialis* (d), *Oncosiphon suffruticosum* (d), *Arctotheca calendula*, *Foveolina tenella*, *Hebenstretia repens*, *Helichrysum litorale*, *Nemesia versicolor*, *Senecio arenarius*, *Ursinia anthemoides* subsp. *anthemoides*. Geophytic Herbs: *Trachyandra ciliata*, *T. divaricata*. Succulent Herbs: *Dorotheanthus bellidiformis* (d), *Conicosia pugioniformis* subsp. *pugioniformis*, *Mesembryanthemum guerichianum*, *Senecio littoreus*. Graminoids: *Bromus pectinatus* (d), *Ehrharta calycina*, *E. villosa* var. *villosa*, *Schismus barbatus*, *Tribolium echinatum*.

J.C. Manning

Figure 4.133 FS 4 Saldanha Limestone Strandveld: Outcrops of Tertiary limestone sediments in the Langebaan area (West Coast) supporting endemic-rich flora also containing notable succulent elements (including *Antimima ventricosa*, *Dorotheanthus bellidiformis Ruschia* species, *Zygophyllum* species and the like).

Biogeographically Important Taxa (all West Coast endemics) Low Shrub: *Afrolimon capense* (d). Succulent Shrub: *Prenia pallens* subsp. *pallens*. Herbs: *Amellus asteroides*, *Grielum grandiflorum*. Geophytic Herb: *Ferraria densepunctulata*. Succulent Herb: *Tetragonia chenopodioides*. Graminoids: *Cladoraphis cyperoides*, *Thamnochortus spicigerus*.

Endemic Taxa Geophytic Herbs: *Hessea mathewsii*, *Romulea elliptica*.

Conservation Endangered. Target 24%. Some 11% statutorily conserved in the West Coast National Park and Yzerfontein Nature Reserve and a very small portion also in private conservation areas such as Jakkalsfontein and West Point. More than a half has already been transformed for cultivation, road building or by urban development. Serious alien infestation is caused by trees such as *Acacia cyclops* and *A. saligna* and herbs including *Bromus diandrus* and *Medicago hispida*. Erosion generally very low.

References Boucher (1982, 1983, 1987, 1996c), Boucher & Rode (1996a, b, 1997a, b, c, d, 1999).

FS 4 Saldanha Limestone Strandveld

VT 34 Strandveld of West Coast (92%) (Acocks 1953). *Nenax–Maytenus–Zygophyllum* Limestone Evergreen Shrubland, *Pteronia uncinata* Limestone Evergreen Dwarf Shrubland (Boucher & Jarman 1977). West Coast Strandveld p.p. (Boucher 1983). LR 4 Dune Thicket (100%) (Low & Rebelo 1996). BHU 4 Langebaan Fynbos/Thicket Mosaic (100%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: Very limited area with a larger patch on the Kliprug ridge between Saldanha and Paternoster, with several smaller outliers including those between Saldanha and north of Club Mykonos on the Langebaan Lagoon. Unmapped are small outcrops at Yzerfontein and on the tip of Langebaan Peninsula. Altitude 20–120 m.

Vegetation & Landscape Features Slightly undulating ridges and steeper coastal slopes supporting low shrublands built of low succulent-stemmed and deciduous, fleshy leaved shrubs in deeper soils. Patches of prostrate, succulent-leaved dwarf shrubs and annual or geophytic herbs occupy cracks or shallow depressions in the exposed limestone.

Geology & Soils Shallow sandy soil on hardpan Tertiary limestone of the Sandveld Group. Dominant land types Fc and Hb.

Climate Mainly cyclonic rainfall varying from approximately 250 mm in the north to 350 mm in the south, almost exclusively in winter (overall MAP is around 300 mm). Mean daily maximum and minimum temperatures 25.3°C and 8.0°C for February and July/August, respectively. For other climate characteristics, see FS 2 Saldanha Granite Strandveld as well the climate diagram for FS 4 Saldanha Limestone Strandveld (Figure 4.128).

Important Taxa Tall Shrubs: *Euclea racemosa* subsp. *racemosa* (d), *Nylandtia spinosa*, *Rhus glauca*. Low Shrubs: *Chrysanthemoides monilifera* (d), *Exomis microphylla*, *Pteronia divaricata*. Succulent Shrubs: *Aloe perfoliata*, *Cheiridopsis rostrata*, *Euphorbia mauritanica*, *Jordaaniella dubia*, *Lycium tetrandrum*, *Othonna cylindrica*, *O. floribunda*, *Ruschia tumidula*, *Zygophyllum cordifolium*, *Z. morgsana*. Semiparasitic Shrub: *Thesium spinosum*. Herbs: *Dimorphotheca pluvialis* (d), *Arctotis hirsuta*, *Lyperia tristis*, *Nemesia versicolor*, *Oncosiphon grandiflorum*, *Ursinia anthemoides* subsp. *anthemoides*, *Zaluzianskya villosa*. Geophytic Herbs: *Babiana tubulosa* var. *tubiflora*, *Oxalis compressa*, *O. obtusa*. Succulent Herbs: *Dorotheanthus bellidiformis* (d), *Mesembryanthemum guerichianum*. Graminoids: *Ehrharta calycina*, *E. villosa* var. *villosa*, *Festuca scabra*, *Ficinia lateralis*, *Ischyrolepis eleocharis*.

Biogeographically Important Taxa (all West Coast endemics) Low Shrubs: *Afrolimon capense* (d), *Asparagus capensis* var. *litoralis*. Herb: *Zaluzianskya parviflora*. Graminoid: *Thamnochortus spicigerus*.

Endemic Taxa Low Shrub: *Muraltia harveyana*. Succulent Shrub: *Cephalophyllum rostellum*. Herbs: *Felicia elongata*, *Limonium acuminatum*, *Manulea augei*. Geophytic Herbs: *Daubenya zeyheri*, *Gladiolus caeruleus*, *Ixia purpureorosea*, *Moraea calcicola*, *Romulea barkerae*.

Conservation Endangered. Target 24%. None conserved in statutory conservation areas and only a small fraction protected in the Swartriet Private Nature Reserve. About 40% has been transformed for cultivation or by development of coastal settlements. Some portions are under heavy grazing pressure. Aliens *Acacia cyclops* and *A. saligna* can become a problem in

places. Erosion generally very low. This vegetation unit is rich in Red Data plants (at least 20 species, some of them restricted to this unit).

References Boucher & Jarman (1977), Boucher (1982, 1983, 1987, 1995, 1996c), Bloemhoff & Craven (1990), Boucher & Rode (1996a, b, 1997a, b, c, d, 1999), Boucher & Schloms (1999), L. Mucina (unpublished data).

FS 5 Langebaan Dune Strandveld

VT 34 Strandveld of West Coast (73%) (Acocks 1953). LR 4 Dune Thicket (73%) (Low & Rebelo 1996). West Coast Strandveld (61%) (Moll & Bossi 1983). BHU 4 Langebaan Fynbos/Thicket Mosaic (95%) (Cowling et al. 1999b, Cowling & Heijnis 2001). Including *Maytenus–Kedrostis* Consolidated-dune Dense Evergreen Shrubland, *Willdenowia striata* Consolidated-dune Dense Evergreen Restioid Shrubland, *Thamnochortus spicigerus* Dune Dense Tall Restioid Herbland (Boucher & Jarman 1977). West Coast Strandveld p.p. (Boucher 1983). *Euclea racemosa–Zygophyllum morgsana* Shrublands (Boucher 1987).

Distribution Western Cape Province: This strandveld occurs in three large disconnected patches: one is a narrow coastal strip from Elands Bay to the mouth of the Great Berg River at Velddrif, the second one covers parts from Britannia Bay past Paternoster to Danger Bay near Saldanha Bay, while the last one surrounds Langebaan Lagoon from the north on the Langebaan Peninsula at Donkergat west of the lagoon and Langebaan, east of the lagoon, via Geelbek to Yzerfontein continuing as a very narrow strip along the West Coast seaboard as far south as Silverstroomstrand at Bokbaai (west of Atlantis). Altitude 0–100 m.

Vegetation & Landscape Features Flat to slightly undulating old coastal dune systems and stabilised inland duneveld supporting closed, evergreen, up to 2 m tall, sclerophyllous shrubland with prominent annual herbaceous flora occurring in gaps (and forming spectacular displays, especially after good rain in late winter).

Geology & Soils Deep Tertiary to Recent sands and calcrete of marine origin. Dominant land types Hb (slightly prevailing), Fc and Ha.

Climate Mainly cyclonic rainfall varying from approximately 230 mm in the north to 355 mm in the south, almost exclusively in winter and accompanied by frequent and strong northwesterly winds and cooler temperatures. Mean daily maximum and minimum temperatures 26.1°C and 7.8°C for February and July, respectively. Mean monthly maximum and minimum temperatures for Cape Columbine 29.8°C and 6.1°C for March and July, respectively. Southeasterly winds prevail in summer. Fog and dew contribute to the moisture in summer and autumn (especially in the northern part of the unit). Frost an infrequent phenomenon. See also climate diagram for FS 5 Langebaan Dune Strandveld (Figure 4.128).

L. Mucina

Figure 4.135 FS 5 Langebaan Dune Strandveld: Coastal dune strandveld with *Chrysanthemoides incana* (Asteraceae) and prominent *Euphorbia gorgonias* at St Helena Bay, north of Vredenburg (Western Cape).

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Figure 4.134 FS 5 Langebaan Dune Strandveld: Dense strandveld shrubland with *Pteronia divaricata* (yellow Asteraceae) and *Euphorbia burmannii* on coastal dunes on the northeastern bank of the Langebaan Lagoon in the West Coast National Park (Western Cape).

Important Taxa Tall Shrubs: *Euclea racemosa* subsp. *racemosa* (d), *Metalasia muricata*, *Morella cordifolia*, *Olea exasperata*, *Rhus glauca*, *R. laevigata*. Low Shrubs: *Chrysanthemoides monilifera* (d), *Pteronia divaricata* (d), *Salvia africana-lutea* (d), *Ballota africana*, *Chironia baccifera*, *Chrysanthemoides incana*, *Clutia daphnoides*, *Eriocephalus africanus* var. *africanus*, *E. racemosus*, *Helichrysum niveum*, *Lebeckia multiflora*, *Maytenus lucida*, *Pterocelastrus tricuspidatus*, *Putterlickia pyracantha*. Succulent Shrubs: *Zygophyllum morgsana* (d), *Cotyledon orbiculata* var. *dactylopsis*, *C. orbiculata*

var. *spuria*, *Crassula dichotoma*, *Didelta carnosa*, *Euphorbia burmannii*, *E. mauritanica*, *Jordaaniella dubia*, *Othonna carnosa*, *O. floribunda*, *Pelargonium fulgidum*, *Ruschia caroli*, *R. cymosa*, *Tetragonia fruticosa*, *Tylecodon paniculatus*. Woody Climber: *Cissampelos capensis*. Semiparasitic Shrubs: *Osyris compressa*, *Thesium spinosum*. Herbs: *Oncosiphon suffruticosum* (d), *Helichrysum litorale*. Geophytic Herbs: *Babiana tubulosa* var. *tubiflora*, *Trachyandra divaricata*. Succulent Herbs: *Carpobrotus acinaciformis* (d), *Dorotheanthus bellidiformis* (d), *Carpobrotus edulis*, *Conicosia pugioniformis* subsp. *pugioniformis*, *Crassula ammophila*, *Mesembryanthemum guerichianum*. Herbaceous Climbers: *Didymodoxa capensis*, *Kedrostis nana*. Graminoids: *Ehrharta villosa* var. *villosa* (d), *Willdenowia incurvata* (d), *Chaetobromus involucratus* subsp. *dregeanus*, *C. involucratus* subsp. *involucratus*, *Festuca scabra*, *Ficinia secunda*, *Ischyrolepis eleocharis*, *Stipa dregeana*, *Thamnochortus erectus*.

Biogeographically Important Taxa (all West Coast endemics) Low Shrubs: *Afrolimon peregrinum* (d), *Asparagus capensis* var. *litoralis*. Succulent Shrubs: *Euphorbia caput-medusae*, *Pelargonium gibbosum*, *Ruschia geminiflora*. Woody Succulent Climber: *Zygophyllum fulvum*. Herbs: *Grielum grandiflorum*, *Zaluzianskya parviflora*. Geophytic Herbs: *Babiana tubulosa* var. *tubulosa*, *Gladiolus griseus*. Graminoid: *Cladoraphis cyperoides*.

Endemic Taxon Semiparasitic Shrub: *Thesium litoreum*.

Conservation Vulnerable. Target 24%. Almost 30% statutorily conserved in the West Coast National Park and in Rocherpan, SAS Saldanha, Columbine and Yzerfontein Nature Reserves. An additional 1% is protected in private reserves such as Groot Paternoster, Jakkalsfontein, Swartriet and Grotto Bay. Some 35% already transformed for cultivation and by urban sprawl. Alien *Acacia cyclops* and *A. saligna* have infested broad stretches of this vegetation unit. Erosion generally very low.

Remarks This is an intermediate strandveld type containing elements from the north and from the south. Sporadic local patches of FS 1 Lambert's Bay Strandveld (not mapped due to small extent) intrude into the Langebaan Dune Strandveld as far south as St Helena Bay. Species such as *Maytenus lucida*, *Rhus pterota* and *Osyris compressum*, conspicuous in this vegetation unit, are absent in the strandveld communities further north along the West Coast.

References Boucher & Jarman (1977), Van Rooyen (1981), Boucher (1982, 1983, 1986, 1987, 1989a, b, 1992, 1993, 1998e, 1999e, f), Bloemhoff & Craven (1990), Heydenrych (1995), Gray (1997), Boucher & Rode (1999), Boucher & Schloms (1999).

FS 6 Cape Flats Dune Strandveld

VT 47 Coastal Macchia (61%) (Acocks 1953). *Pterocelastrus* Coast Dune Scrub, *Metalasia* Coast Dune Fynbos (Taylor 1972b). *Colpoon–Rhus* Dune Scrub (Boucher 1978). Broad-Leaved Thicket (Taylor 1984a). West Coast Strandveld p.p. (Boucher 1983). *Cassine barbara–Polygala myrtifolia* Coastal Community, *Tetragonia decumbens–Sideroxylon inerme* Mature Hind-dune Community, *Tetragonia decumbens–Metalasia muricata* Dune Community (O'Callaghan 1990). LR 4 Dune Thicket (76%) (Low & Rebelo 1996). BHU 5 Cape Flats Fynbos/Thicket Mosaic (48%), BHU 1 South West Dune Pioneer (22%) (Cowling et al. 1999b, Cowling & Heijnis 2001).

Distribution Western Cape Province: This unit occurs as four discontinuous regions—the largest patch spans the south coast of False Bay (between Gordon's Bay and Muizenberg) and penetrates deep into the Cape Flats as a broad wedge as far north as Bellville, the other patch spans Silverstroomstrand and Table Bay (Cape Town) and includes the Atlantis dune plume, the third region is a series of small patches covering coastal dune pockets on the Cape Peninsula, while the last patch is situated on Robben Island. Altitude 0–80 m, but reaching 200 m in places.

Vegetation & Landscape Features Flat to slightly undulating (dune fields) landscape covered by tall, evergreen, hard-leaved shrubland with abundant grasses and annual herbs in gaps.

Geology & Soils Built mainly of Tertiary to Recent calcareous sand of marine origin and overlying metasediments of the Tygerberg Formation (Malmesbury Group, Namibian Erathem). Outcrops of Sandveld Group limestone (hardpan) are found on the False Bay coast (Cape Peninsula and especially the Wolvengat area). Dominant land type Ha (about 50%), with Hb and Ga playing subordinate roles.

Climate Exclusive winter-rainfall regime with mean annual rainfall varying from approximately 350 mm in the north to 560 mm in the south. The winter rains are accompanied by strong northwesterly winds and cooler temperatures. Mean daily maximum and minimum temperatures 26.7°C and 7.5°C for February and July, respectively. Mean monthly maximum and minimum temperatures for Cape Town International Airport 34.3°C and 1.1°C for February and July, respectively. Winds are southerly or southeasterly in summer. Frost very infrequent. See also climate diagram for FS 6 Cape Flats Dune Strandveld (Figure 4.128).

Important Taxa Tall Shrubs: *Euclea racemosa* subsp. *racemosa* (d), *Metalasia muricata* (d), *Rhus glauca* (d), *Morella cordifolia*, *Nylandtia spinosa*, *Olea exasperata*, *Rhus crenata*, *R. laevigata*, *R. lucida*. Low Shrubs: *Chrysanthemoides monilifera* (d), *Cullumia squarrosa* (d), *Pterocelastrus tricuspidatus* (d), *Salvia africana-lutea* (d), *Cassine peragua* subsp. *barbara*, *Chironia baccifera*, *Eriocephalus africanus* var. *africanus*, *E. racemosus*, *Helichrysum niveum*, *H. teretifolium*, *Lessertia fruticosa*, *Otholobium bracteolatum*, *Passerina paleacea*, *Phylica ericoides*, *Putterlickia pyracantha*, *Robsonodendron maritimum*. Succulent Shrubs:

L. Mucina

Figure 4.136 FS 6 Cape Flats Dune Strandveld: Strandveld shrublands with typical hemispheric cushion-forming shrubs *Metalasia muricata* (Asteraceae) and *Tetragonia fruticosa* (Aizoaceae) dominant here at the Cape of Good Hope (with the famous Cape itself in the background, right).

L. Mucina

Figure 4.137 FS 7 Overberg Dune Strandveld: Coastal dune vegetation dominated by *Thamnochortus insignis* (large-tussock Restionaceae), *Metalasia muricata* (Asteraceae) and *Ischyrolepis eleocharis* (creeping Restionaceae) in De Mond Nature Reserve near Arniston (Western Cape).

Tetragonia fruticosa (d), *Cotyledon orbiculata* var. *spuria*, *Euphorbia mauritanica*, *Jordaaniella dubia*, *Pelargonium fulgidum*, *Ruschia macowanii*, *Tylecodon grandiflorus*, *Zygophyllum flexuosum*. Woody Climbers: *Cissampelos capensis*, *Solanum africanum*. Semiparasitic Shrubs: *Osyris compressa*, *Thesidium fragile*. Semiparasitic Epiphytic Shrub: *Viscum capense*. Herbs: *Helichrysum crispum* (d), *Adenogramma glomerata*, *Arctotheca calendula*, *Cineraria geifolia*, *Galium tomentosum*, *Helichrysum litorale*, *Knowltonia capensis*, *Lyperia tristis*, *Nemesia versicolor*, *Senecio elegans*, *Ursinia anthemoides* subsp. *anthemoides*, *Zaluzianskya villosa*. Geophytic Herbs: *Babiana tubulosa* var. *tubiflora*, *Brunsvigia orientalis*, *Chasmanthe aethiopica*, *Geissorhiza exscapa*, *Trachyandra ciliata*. Succulent Herbs: *Carpobrotus acinaciformis*, *C. edulis*, *Conicosia pugioniformis* subsp. *pugioniformis*, *Senecio littoreus*. Herbaceous Climbers: *Astephanus triflorus*, *Cynanchum africanum*, *C. obtusifolium*, *Didymodoxa capensis*, *Kedrostis nana*. Graminoids: *Ehrharta villosa* var. *villosa* (d), *Ischyrolepis eleocharis* (d), *Chaetobromus involucratus* subsp. *dregeanus*, *C. involucratus* subsp. *involucratus*, *Ehrharta calycina*, *Ficinia lateralis*, *F. ramosissima*, *F. secunda*, *Thamnochortus erectus*, *Willdenowia teres*.

Biogeographically Important Taxa (all West Coast endemics) Low Shrub: *Afrolimon peregrinum* (d). Succulent Shrubs: *Pelargonium gibbosum*, *Ruschia geminiflora*. Herb: *Grielum grandiflorum*. Geophytic Herb: *Gladiolus griseus*. Graminoids: *Cladoraphis cyperoides*, *Thamnochortus spicigerus*.

Endemic Taxon Succulent Shrub: *Lampranthus tenuifolius*.

Conservation Endangered. Target 24%. More than 6% statutorily conserved in the Table Mountain National Park, Blouberg, Driftsands, Wolfgat and Raapenberg Nature Reserves as well as in Rondevlei and Zandvlei Bird Sanctuaries. Private nature reserves protect about 4% of the unit (Blaauw Mountain, Koeberg, Lourens River, Rietvlei, Somchem). Almost 40% already transformed by urban sprawl, road building or by cultivation. Alien species of *Acacia*, pines and gum trees (*Eucalyptus*) have replaced the original strandveld vegetation in large areas. Erosion generally very low.

Remark *Sideroxylon inerme*, a conspicuous common species along the southern coastal strandveld, finds its westernmost distribution limit in this vegetation type and it does not extend northwards into the drier strandveld types.

References Taylor (1972b, 1984a), Milton (1976), Boucher (1978, 1982, 1983, 1987, 1997b, 1998b, 1999a, g), O'Callaghan (1990), Berry (1991), Privett (1998).

FS 7 Overberg Dune Strandveld

VT 47 Coastal Macchia (90%) (Acocks 1953). South Coast Strandveld (78%) (Moll & Bossi 1983). LR 4 Dune Thicket (84%) (Low & Rebelo 1996). BHU 6 Agulhas Fynbos Thicket Mosaic (81%) (Cowling et al. 1999b, Cowling & Heijnis 2001). Including South Coast Strandveld (Moll et al. 1984). Dune Thicket (Rebelo et al. 1991).

Distribution Western Cape Province: Scattered patches from Rooiels (Cape Hangklip area) as far east as Cape Infanta at the mouth of the Breede River, with the largest one surrounding the Agulhas Peninsula—as a rule bordering on coastal limestone formations. Altitude 0–100 m, but reaching 160 m in places.

Vegetation & Landscape Features Flat or slightly undulating dune fields of Die Plaat near Stanford and those of De Hoop, supporting up to 4 m tall, closed, evergreen, hard-leaved shrublands in moist dune slacks and wind-protected valleys and up to 1 m tall, coastal thicket in many places wind-shorn along exposed littoral situations.

Geology & Soils Deep, Recent marine-derived calcareous sands forming dunes that line the coast (Quaternary Strandveld Formation of the Bredasdorp Group), to shelly, shallow-marine sandstones and limestones of the Bredasdorp Group deposited on underlying Table Mountain Group sandstone. The most important land types include Hb (37%), Ha (31%) and Fc (18%).

Climate Mainly cyclonic rainfall varying from approximately 400 mm in the east to 600 mm in the west, mainly in winter, but still with considerable summer rainfall in the eastern regions of the unit. The winter rains are accompanied by strong northwesterly winds and cooler temperatures. The winds tend to be strong southwesterly (trade winds with average velocity of 35 km per hour) in summer. Mean daily maximum and minimum temperatures 25.1°C and 7.0°C for January and July, respectively. Mean monthly maximum and minimum temperatures for Cape Agulhas 27.1°C and 7.3°C for January and June, respectively. No incidences of snowfalls have been recorded; frost is infrequent and hail occurs occasionally. Dense mist banks regularly occur through the Overberg region in autumn and winter. See also climate diagram for FS 7 Overberg Dune Strandveld (Figure 4.128).

Important Taxa Tall Shrubs: *Euclea racemosa* subsp. *racemosa* (d), *Metalasia muricata* (d), *Rhus crenata* (d), *R. glauca* (d), *R. laevigata* (d), *Chionanthus foveolatus*, *Cussonia thyrsiflora*, *Gymnosporia buxifolia*, *Morella cordifolia*, *Myrsine africana*, *Olea exasperata*, *Passerina corymbosa*, *Rhus lucida*, *R. undulata*, *Sideroxylon inerme*, *Tarchonanthus littoralis*. Low Shrubs: *Chrysanthemoides monilifera* (d), *Passerina paleacea* (d), *P. rigida* (d), *Pterocelastrus tricuspidatus* (d), *Aspalathus forbesii*,

Ballota africana, *Carissa bispinosa* subsp. *bispinosa*, *Cassine peragua* subsp. *barbara*, *Chironia baccifera*, *Eriocephalus africanus* var. *africanus*, *Felicia amelloides*, *Helichrysum niveum*, *H. teretifolium*, *Lauridia tetragona*, *Otholobium bracteolatum*, *Phylica axillaris*, *P. ericoides*, *Polygala myrtifolia*, *Psoralea repens*, *Robsonodendron maritimum*. Succulent Shrubs: *Crassula nudicaulis*, *Drosanthemum candens*, *Jordaaniella dubia*, *Osteospermum fruticosum*, *Othonna dentata*, *Tetragonia decumbens*, *T. fruticosa*, *T. spicata*. Woody Climbers: *Asparagus aethiopicus*, *Cissampelos capensis*, *Solanum africanum*. Semiparasitic Shrubs: *Thesidium fragile* (d), *Osyris compressa*. Herbs: *Helichrysum crispum* (d), *Senecio elegans* (d), *Cineraria geifolia*, *Hebenstretia repens*, *Helichrysum litorale*, *Knowltonia capensis*, *Silene crassifolia*, *Stachys aethiopica*. Geophytic Herbs: *Brunsvigia orientalis*, *Chasmanthe aethiopica*, *Romulea obscura*. Succulent Herbs: *Carpobrotus acinaciformis* (d), *C. edulis*, *Crassula expansa* subsp. *expansa*. Herbaceous Climbers: *Astephanus triflorus*, *Cynanchum africanum*, *Kedrostis nana*. Graminoids: *Ischyrolepis eleocharis* (d), *Cynodon dactylon*, *Ehrharta erecta*, *E. villosa* var. *villosa*, *Ficinia lateralis*, *Thamnochortus erectus*.

Biogeographically Important Taxon (South Coast endemic) Low Shrub: *Berkheya coriacea*.

Endemic Taxa Succulent Shrub: *Lampranthus salteri*. Geophytic Herb: *Gladiolus carmineus*.

Conservation Least threatened. Target 36%. Some 30% statutorily conserved in De Hoop, Walker Bay and De Mond Nature Reserves and in the Agulhas National Park. A further 11% of the unit is protected in private conservation areas, such as Andrewsfield, Brandfontein-Rietfontein, Groot Hagelkraal, Hoek-van-die-Berg, Kleinrivier, Paapekuilfontein and Waterkop. More than 5% has been transformed by urban development and cultivation. Established thickets of alien *Acacia cyclops*, *A. saligna* and *Leptospermum laevigatum* are of serious concern. Erosion very low and low.

Remarks Parts of this vegetation unit have a drier climate than the FS 8 Blombos Strandveld with fewer components typical of coastal thickets fringing the seaboards further east. It has also fewer succulents than the strandveld types along the western seaboard.

References Boucher (1974, 1977, 1978, 1994b, 1995, 1998a, 1999c), Van der Merwe (1977a), Cowling et al. (1988), Taylor & Boucher (1993), De Hoop Nature Reserve Planning Committee (2001), Zietsman & Bredenkamp (2006), L. Mucina (unpublished data).

FS 8 Blombos Strandveld

VT 47 Coastal Macchia (91%) (Acocks 1953). Dune Fynbos (93%) (Moll & Bossi 1983). LR 4 Dune Thicket (97%) (Low & Rebelo 1996). BHU 7 Stilbaai Fynbos/Thicket Mosaic (81%) (Cowling et al. 1999b, Cowling & Heijnis 2001). STEP Gouritz Dune Thicket (36%), STEP Still Bay Dune Thicket (27%) (Vlok & Euston-Brown 2002, Vlok et al. 2003).

Distribution Western Cape Province: Narrow strip of interrupted patches along the coast of the Indian Ocean between Witsand and Gouritsmond (bordering on the easternmost occurrence of coastal limestone). Altitude 0–180 m.

Vegetation & Landscape Features Flat or slightly undulating coastal landscapes with dense, evergreen, sclerophyllous shrublands and thickets, with a poorly developed undergrowth layer. The thicket vegetation is best developed in dune slacks, where it is well protected from occasional fires that may penetrate the coastal zone from the inland areas and from salt-laden onshore winds that cause stunting (0.5 m tall, dense vegetation) in exposed littoral situations.

Geology & Soils Mainly on the Bredasdorp Group limestones and sandstones, but also on younger, unconsolidated lime-rich Strandveld and Waenhuiskrans Formations, which consist of white dune sands with fine shell material and occasionally with calcrete lenses present; in places with an admixture of littoral calcareous or sandstone cobbles. Most important land types Hb (39%), Ha (29%) and Fc (13%).

Climate Mainly cyclonic rainfall varying from approximately 300 mm in the east to 600 mm in the west. Precipitation is weakly bimodal, with peaks in spring and autumn. Morning fogs are common in winter. Mean daily maximum and minimum temperatures 25.0°C and 6.4°C for February and July, respectively. The prevailing winds are easterly and westerly, with a sea breeze influence on the vegetation. Strong and dry off-shore berg winds occur in late autumn and early winter, increasing the chance of veld fires. Frost incidence infrequent. See also climate diagram for FS 8 Blombos Strandveld (Figure 4.128).

Important Taxa Small Trees: *Chionanthus foveolatus*, *Clausena anisata*, *Zanthoxylum capense*. Tall Shrubs: *Chrysanthemoides monilifera* (d), *Metalasia muricata* (d), *Pterocelastrus tricuspidatus* (d), *Azima tetracantha*, *Cussonia thyrsiflora*, *Euclea racemosa* subsp. *racemosa*, *Grewia occidentalis*, *Gymnosporia capitata*, *Maytenus procumbens*, *Morella cordifolia*, *Mystroxylon aethiopicum*, *Olea exasperata*, *Ptaeroxylon obliquum*, *Putterlickia pyracantha*, *Rhus crenata*, *R. glauca*, *R. longispina*, *R. lucida*, *Sideroxylon inerme*, *Tarchonanthus littoralis*. Low Shrubs:

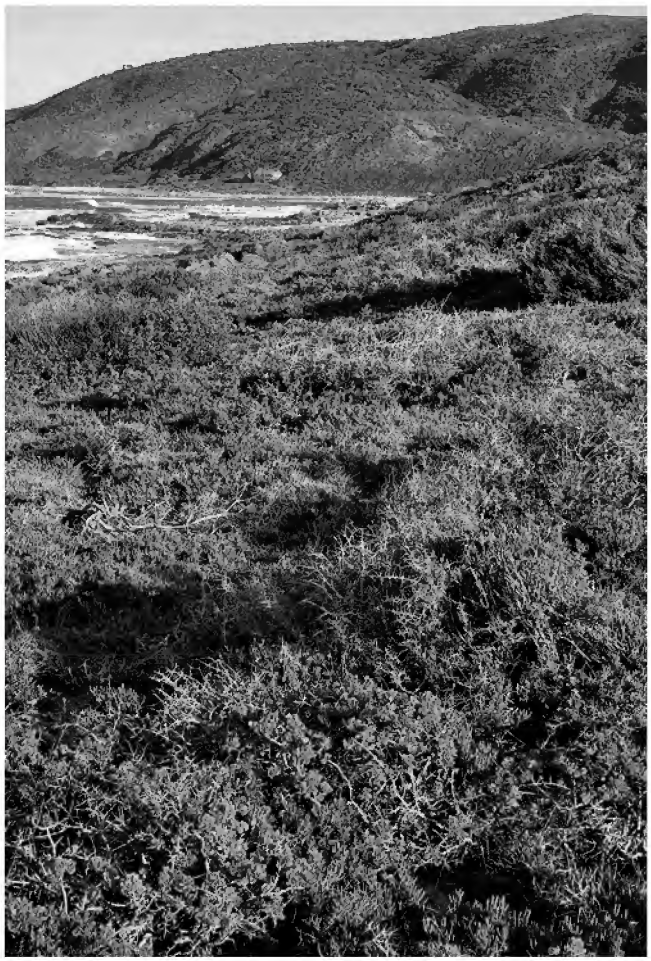

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Figure 4.138 FS 8 Blombos Strandveld: Dense coastal thicket kept low by strong winds and the influence of salt spray, with *Exomis microphylla* (Chenopodiaceae), *Tetragonia fruticosa* (Aizoaceae) and *Rhus crenata* (Anacardiaceae) at Groot Jongensfontein near Still Bay (Western Cape).

Exomis microphylla (d), *Passerina rigida* (d), *Salvia africana-lutea* (d), *Aspalathus alopecurus*, *Ballota africana*, *Carissa bispinosa* subsp. *bispinosa*, *Cassine peragua* subsp. *barbara*, *Chironia baccifera*, *Eriocephalus africanus* var. *africanus*, *Lauridia tetragona*, *Passerina galpinii*, *Phylica axillaris*, *Polygala myrtifolia*, *Robsonodendron maritimum*. Succulent Shrubs: *Zygophyllum morgsana* (d), *Osteospermum fruticosum* (d), *Crassula nudicaulis*, *C. pubescens* subsp. *pubescens*, *Euphorbia mauritanica*, *Jordaaniella dubia*. Woody Climbers: *Rhoicissus digitata*, *Solanum africanum*. Woody Succulent Climber: *Sarcostemma viminale*. Semiparasitic Shrub: *Thesidium fragile* (d). Soft Shrub: *Hypoestes aristata*. Herbs: *Cineraria geifolia*, *Commelina africana*, *Galium tomentosum*, *Helichrysum litorale*, *Stachys aethiopica*. Geophytic Herbs: *Brunsvigia orientalis*, *Chasmanthe aethiopica*, *Trachyandra divaricata*. Succulent Herbs: *Carpobrotus acinaciformis* (d), *C. edulis*, *Crassula expansa* subsp. *expansa*. Herbaceous Climbers: *Astephanus triflorus*, *Cynanchum ellipticum*. Herbaceous Succulent Climber: *Pelargonium peltatum*. Graminoids: *Cynodon dactylon*, *Ehrharta delicatula*, *E. villosa* var. *villosa*, *Ficinia indica*, *F. lateralis*, *F. ramosissima*, *Thamnochortus erectus*.

Biogeographically Important Taxa (both South Coast endemics) Low Shrub: *Berkheya coriacea*. Geophytic Herb: *Freesia alba*.

Endemic Taxa Low Shrub: *Aspalathus arenaria*. Succulent Shrub: *Lampranthus galpiniae*.

Conservation Least threatened. Target 36%. More than 20% statutorily conserved in the Kleinjongensfontein, Geelkrans, Blomboschfontein, Skulpiesbaai and Pauline Bohnen Nature Reserves. A further 11% enjoys protection in private reserves such as Duiwenhoksriviermond, Rein's Coastal (Gouriqua), Vergaderingskop, Blombos, Die Duine and Orca. The vegetation is relatively well preserved and has not experienced much transformation, except for local infestation by alien *Acacia cyclops* and *A. saligna*. Erosion generally very low.

References Muir (1929), Rebelo et al. (1991), Boucher & Rode (1995a, b), Boucher (1997d), Vlok & Euston-Brown (2002), Vlok et al. (2003).

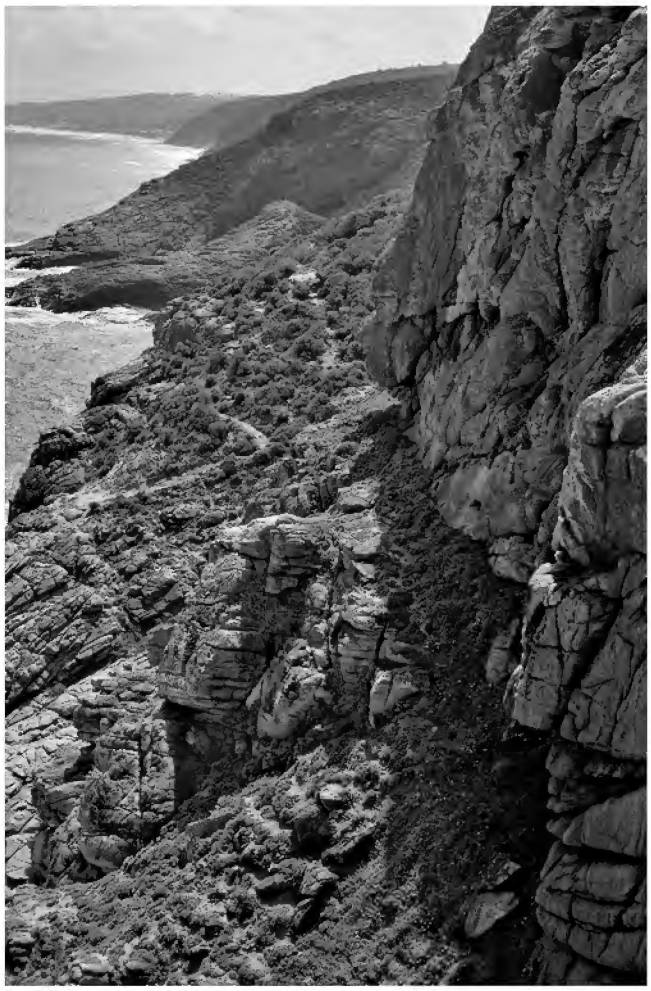

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Figure 4.139 FS 9 Groot Brak Dune Strandveld: Steep coastal granite cliffs supporting low wind-sheared coastal thickets, near Herolds Bay south of George (Western Cape).

FS 9 Groot Brak Dune Strandveld

VT 46 Coastal Renosterbosveld (53%) (Acocks 1953). Gouritz River Scrub (Acocks 1988). LR 63 South and South-west Coast Renosterveld (86%) (Low & Rebelo 1996). BHU 34 Riversdale Coast Renosterveld (47%), BHU 28 Blanco Fynbos/Renosterveld Mosaic (27%) (Cowling et al. 1999b, Cowling & Heijnis 2001). STEP Herbertsdale Renoster Thicket (67%) (Vlok & Euston-Brown 2002, Vlok et al. 2003).

Distribution Western Cape Province: Coastal stretches between the mouth of the Gouritz River as far east as Victoria Bay near the Wilderness, with by far the largest area covering the flats north of Mossel Bay (along the lower reaches of the Groot Brak, Klein Brak and Hartenbos Rivers) and extending up to 17 km from the coast. Altitude 0–180 m.

Vegetation & Landscape Features Flats, undulating landscapes (stabilised dunes) and steep coastal slopes, covered by dense and tall (up to 3 m), spiny, sclerophyllous scrub with gaps supporting shrublands with ericoids or succulent-leaved shrubs. The graminoid layer is sparse and short.

Geology & Soils Mostly underlain by the clastic sedimentary rocks of the Kirkwood Formation (Mesozoic Uitenhage Group). In the east, quartzite, schist and phyllite of the Kaaimans Group (Namibian Erathem) and Cape Granite (edges of high coastal cliffs) are also present. In parts along the coast, these rocks are covered by the unconsolidated dune sand of the Strandveld Formation (Bredasdorp Group). Most important land types Db and Dc.

Climate MAP varies between approximately 350 mm in the west to 750 mm in the east, with approximately 40% of the rain falling in summer (October–March) and 60% in winter (April–September). Mean daily maximum and minimum temperatures 26.8°C and 7.7°C for February and July, respectively. Mean monthly maximum and minimum temperatures for Cape St Blaize 29.0°C and 7.1°C for April and August, respectively. See also climate diagram for FS 9 Groot Brak Dune Strandveld (Figure 4.128).

Important Taxa Small Trees: *Chionanthus foveolatus*, *Clausena anisata*. Tall Shrubs: *Azima tetracantha*, *Cussonia thyrsiflora*, *Diospyros dichrophylla*, *Euclea racemosa* subsp. *racemosa*, *Grewia occidentalis*, *Gymnosporia buxifolia*, *Maytenus procumbens*, *Metalasia muricata*, *Morella cordifolia*, *Myrsine africana*, *Mystroxylon aethiopicum*, *Olea exasperata*, *Pterocelastrus tricuspidatus*, *Putterlickia pyracantha*, *Rhus crenata*, *R. glauca*, *R. longispina*, *R. lucida*, *Schotia afra* var. *afra*, *Sideroxylon inerme*, *Tarchonanthus littoralis*. Low Shrubs: *Asparagus suaveolens*, *Ballota africana*, *Carissa bispinosa* subsp. *bispinosa*, *Chironia baccifera*, *Clutia daphnoides*, *Eriocephalus africanus* var. *africanus*, *Helichrysum teretifolium*, *Lauridia tetragona*, *Phylica axillaris*, *Polygala myrtifolia*. Succulent Shrubs: *Aloe arborescens* (d), *Cotyledon orbiculata* var. *dactylopsis*, *Crassula perforata*, *C. pubescens* subsp. *pubescens*, *Euphorbia burmannii*, *E. mauritanica*, *Tetragonia fruticosa*, *Zygophyllum morgsana*.

Woody Climbers: *Asparagus aethiopicus*, *Cissampelos capensis*, *Rhoicissus digitata*. Woody Succulent Climber: *Sarcostemma viminale*. Semiparasitic Shrubs: *Osyris compressa*, *Thesidium fragile*. Soft Shrub: *Hypoestes aristata*. Herb: *Commelina africana*. Geophytic Herbs: *Brunsvigia orientalis*, *Chasmanthe aethiopica*, *Hesperantha falcata*. Succulent Herbs: *Carpobrotus edulis*, *Crassula expansa* subsp. *expansa*, *Senecio radicans*. Herbaceous Climbers: *Astephanus triflorus*, *Cynanchum obtusifolium*, *Kedrostis nana*. Herbaceous Succulent Climber: *Pelargonium peltatum*. Graminoids: *Cynodon dactylon*, *Ehrharta erecta*, *Ficinia indica*, *Panicum deustum*, *Stipa dregeana*.

Biogeographically Important Taxa (both South Coast endemics) Herb: *Indigofera tomentosa*. Geophytic Herb: *Freesia alba*.

Conservation Endangered. Target 36%. None conserved in statutory conservation areas and only about 1% protected in private reserves (George, Kanon, Blydskap, Kwelanga). Almost half of the region has been transformed for cultivation, by building of roads or by development of coastal settlements. Erosion generally moderate and high, with some areas ranking as low.

References Vlok & Euston-Brown (2002), Vlok et al. (2003), C. Boucher (unpublished data), H.C. Taylor (unpublished data).

10. Credits

The first draft of the introductory text was written by A.G. Rebelo. L. Mucina wrote most of Sections 1.1, 1.3, 1.5, 2.4.1, 5.2, and contributed to 1.4.3. The following sections were rewritten or contributed to by: R.A. Ward wrote most of the geological patterns (Section 2.1), F. Ellis and J.J.N. Lambrechts wrote Section 2.3 (soils), M.C. Rutherford wrote most of the regional climate (Section 2.4.2) and contributed to discussion on boundaries of the Fynbos and Karoo (Section 1.4.2), as well as to the section on climate and ecophysiological response (4.2), F.G.T. Radloff wrote most of the section on large mammal herbivory (Section 4.4.1), L. Scott contributed the section featuring the palaeoecological framework (Section 5.1), Ş.M. Procheş contributed to endemism and species diversity patterns (Sections 6.1 and 6.3), S.D. Johnson contributed extensively to section 4.4.2 (pollination and dispersal), D.M. Richardson wrote the account of the role of alien flora in the Fynbos Biome (Section 7.2) and B.A. Walton made a contribution to the section on renosterveld (3.2). All sections were extensively edited and adapted by A.G. Rebelo, L. Mucina and M.C. Rutherford.

An initial theoretical framework was done by C. Boucher and L. Mucina based on satellite imagery supplied by CapeNature (then Western Cape Nature Conservation Service) and digitised by R.S. Knight and S. Jonas (then Univ. of Western Cape). These were discarded and a redefinition of fynbos and renosterveld units based on geology was done by A.G. Rebelo in consultation with C. Boucher, N. Helme, R.M. Cowling, J.H.J. Vlok, A.B. Low, L. Mucina and M.C. Rutherford. Mapping was done by A.G. Rebelo with GIS help from W.J. Smit. Map units used or used to inform units included unpublished digitised versions provided for the Cederberg by D. Bands (Jonkershoek), Little Karoo by J.H.J. Vlok, Agulhas by D.I.W. Euston-Brown, South and West Coast renosterveld units by N. Helme, and Cape Flats by A.B. Low. Further GIS assistance in the final stages was provided by L.W. Powrie.

The conceptual scheme for the mapping of the Kamiesberg units (FFg 1 and FRg 1) was conceived by A. le Roux, L. Mucina and M.C. Rutherford in concert with the establishment of the mapping boundaries of the surrounding Succulent Karoo units. The boundaries of the unit FFg 1 were replaced by A.G. Rebelo based on the distribution of Proteaceae: this was chosen as the 1 400 m altitude. The original mapped extent of FFq 1 (as suggested by N. Jürgens) has been modified by M.C. Rutherford and L. Mucina.

A.G. Rebelo is sole author of the descriptions of FFh 1, 8–10, FFq 4–6, FFs 1, 5, 8, 20–22, 26, 29, FFt 1–2, FRl 1 and FRs 6, and further contributed to all other vegetation units (for most of which he is the leading author) except for FFd 11, FFq 1 and FS 1–9. L. Mucina is the sole author of the description of FFd 11, wrote all FS units, is the leading author of the units FFs 27–28 and 30–31 as well as of FRd 1–2, FRg 1 and FRs 3 and 5. He further co-authored all FFa units, all FFb units, FFc 1, FFd 1 and 8–9, FFf 2, FFg 1–2, 5, all FFl units, FFs 6–7, 10–12, 17, 19, 25, all FRa units, FRc 2, FRg 2 and FRs 8–10, 13 and 19. C. Boucher participated in all FS units, is the leading author of FFa 4, FFd 8, 10, FRs 4, 17 and further co-authored FFa 1–3, FFc 1, FFd 2–7, 9, FFf 1, FFg 2–3, FFh 6, all FFl units, FFq 2–3, FFs 2–4, 9–16, 19, 23–24, both FRa units, FRg 2, FRs 8–9, 11–15 and 18. N. Helme is the leading author of FFd 1, FRg 3, FRs 11–13 and further co-authored descriptions of FFa 3, both FFf units, FFg 1–4, FFh 2–7, FRa 1, FRc 1, FRg 2 and FRs 1, 7–10 and 15–16. M.C. Rutherford co-authored FFb 2, FFh 4, FFq 1 and 3, FFs 8, 13, 16–18, 23, 27–30 and FRg 1. A.L. Skowno and S.A. Todd co-authored the description of FRs 2. J.A.M. Janssen contributed to the descriptions of FFf 1 and FFs 12. A. le Roux contributed to FFd 1 and FFg 1. B.A. Walton contributed to FFa 3, D.B. Hoare to FFd 11, FRs 19 and D.J. McDonald to FFs 16. N. Jürgens is the sole author of FFq 1.

M.C. Rutherford and L.W. Powrie prepared all climate diagrams and their captions. M.C. Rutherford contributed to the editing of the climate characteristics of all FS units. For all vegetation units M. Rouget, and others within the Directorate of Biodiversity Programmes, Policy & Planning of SANBI, provided quantitative information on conservation status and targets, areas currently conserved and areas transformed for each vegetation unit. W.J. Smit and L.W. Powrie assisted in preparing the data on conservation and transformation, correspondence with other classification schemes, climate, altitude ranges, alien invasive species and distribution of Proteaceae, which were used in the text for all vegetation unit descriptions except for FFs. Introductory texts to the fynbos and renosterveld units (within the section on Descriptions) were written by A.G. Rebelo and edited by L. Mucina. Within the same section L. Mucina contributed the short characteristics of the sandstone and limestone fynbos as well as strandveld.

The initial species lists for most of the FF and FR units have been prepared by A.G. Rebelo, assisted by N. Helme (especially in FR units) and C. Boucher. The lists have been revised in depth by L. Mucina, especially FFs 7, 10–12, 17, 24–26, FFq 2, 5 and 6, FFd 1, 7–8 and 10, FFh 1–2, 5–6 and 10, FFb 1–6 (here also assisted by M.C. Rutherford and L.W. Powrie), FFa 1, 3 (assisted by B.A. Walton) and 4, FFg 1 (using an unpublished list of endemics by N. Helme as an important source), 2, 4 and 5, FFf 2, FFl 1–3, FRs 2–4, 6–7, 9 (assisted by B.A. Walton), 11–15, 18 (assisted by M.C. Rutherford and L.W. Powrie) and 19, FRg 1 (using unpublished lists of species by A. le Roux and N. Helme as important sources) and 3, FRd 1–2, FRa 2 (assisted by B.A. Walton), FRc 1 (assisted by B.A. Walton) and 2. L. Mucina also provided completely new lists for FFs 27–28 and 30–31, FFd 11 and FRs 5. The original species list of FFq 1 was provided by N. Jürgens.

The major sources of the species lists were the unpublished data from the PRECIS system, Acocks database, Protea Atlas Project, conspectus of Cape flora (Goldblatt & Manning 2000b), published phytosociological literature (for details see the References further on) as well as unpublished field records of all authors

involved in this chapter. L.W. Powrie and W.J. Smit assisted with extraction of species lists from the SANBI databases (PRECIS, ACKDAT). We thank the Data Management Section of SANBI (Pretoria) for making these databases accessible to the VEGMAP Project. E.G.H. (Ted) Oliver checked the affiliation of the *Erica* species against particular species lists, while J.C. Manning checked the affiliation of the bulbous plants (including Iridaceae, Hyacinthaceae, Tecophilaeaceae, etc.). The initial species lists of the FS units by C. Boucher have been extensively edited by L. Mucina. The link to all Proteaceae to the Fynbos units were corrected by A.G. Rebelo.

Endemic species lists were extracted from Protea Atlas Project data and the conspectus of Cape flora (Goldblatt & Manning 2000b) by A.G. Rebelo, and from unpublished lists by N. Helme for West and South Coast renosterveld and by A. le Roux and N. Helme for the Kamiesberg. These were checked by E.G.H. (Ted) Oliver and R. Turner (Ericaceae), J.C. Manning (Iridaceae, Hyacinthaceae, Tecophilaeaceae), D. Snyman (Amaryllidaceae), P. Chesselet (Aizoaceae), and A. Schutte-Vlok (Fabaceae) among others, except for Restionaceae, which were checked using Linder (1999) as the major source. N. Helme checked the endemic species lists of the renosterveld units. All lists of endemics were extensively checked by L. Mucina in the final leg of editing.

Most of the photographs were contributed by L. Mucina. Other photographers include D. Gwynne-Evans, J.C. Manning, F.G.T. Radloff, K.J.C. Melvin-Phillips, P. Goldblatt, C. Boucher, A. van Niekerk, L.W. Powrie, M.C. Rutherford, C. Paterson-Jones, J.P. Groenewald and A.V. Köcke. Figures 4.4 to 4.7 were supplied by F. Ellis and J.J.N. Lambrechts and Figures 4.8 and 4.9 were prepared by M.C. Rutherford and L.W. Powrie. Figure 4.78 was constructed by L.W. Powrie and L. Mucina. Tables 4.1 and 4.2 were contributed by L. Mucina and Table 4.3 was prepared by Ş.M. Procheş. The captions to the photographs were created by L. Mucina (with the help of other photographers and expert advice) and edited by A.G. Rebelo.

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These Credits were compiled by L. Mucina, revised by A.G. Rebelo and edited by M.C. Rutherford

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K. Phillips

Succulent Karoo Biome 5

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1. Introduction: Regional and Global Position

The Succulent Karoo Biome covers an interrupted belt of unequal depth spanning the coastal regions near Lüderitz (Namibia), Namaqualand (on and west of the Escarpment), the Hantam, Tanqua and Roggeveld region as well as the Little Karoo (in a broad sense). The latter is a composite region, including karoo landscapes of the western Great Karoo Basin (surrounds of Laingsburg) and northern piedmonts of the Swartberg Mountains (surrounds of Prince Albert) and a series of valleys embraced by west-east stretching Cape Fold Mountain ranges, including those bordering the Succulent Karoo in the north (Witteberg, Klein Swartberg, Groot Swartberg, Grootrivier and Klein Winterhoek Mountains) and those forming barriers in the south (Langeberg, Outeniqua, Tsitsikamma, Baviaanskloof and Groot Winterhoek Mountains). Notable outliers of the biome are found on and around inselbergs of northern Bushmanland (embedded within the Nama-Karoo), in the deep rainshadow valley of the Olifants River (sheltered by the Graafwater and Olifants River Mountains in the west and the Cederberg Mountains in the east), in the upper Breede River Valley in the rainshadow of the Cape Fold Belt mountains and in the form of small patches east of Piketberg, embedded within West Coast renosterveld.

The Succulent Karoo Biome is found mostly west of the western escarpment from the Lüderitz District of Namibia through the western belt of the Northern Cape and Western Cape Provinces, and inland of the Fynbos Biome to the Little Karoo. The biome covers approximately 111 000 km, making it the fourth largest biome in southern Africa after the Savanna, Nama-Karoo and Grassland Biomes. Much of the terrain is flat to gently undulating, such as the western coastal platform, Knersvlakte and Tanqua Karoo. Hilly and more rugged topography occurs in Namaqualand, the Robertson Karoo and Little Karoo and parts of the western escarpment. The extreme altitudinal range is from sea level to about 1 500 m, but most of the area lies below 800 m.

The nomenclature of this biome is probably the most difficult to determine since no single regional, traditional name exists for the whole area. The term Succulent Karoo is regarded as appropriate since, although by no means all the plants of the biome are succulent, succulence is a recurring feature at varying levels of abundance throughout the biome. The term should not be regarded as being limited to the Acocks's (1988) 'Succulent Karoo' Veld Type No. 31.

The Succulent Karoo Biome interfaces with the Fynbos Biome—the biome with which it shares its greatest floristic affinity (Hilton-Taylor 1987)—to the south and east. It borders on Albany Thicket to the east, Nama-Karoo to the north and west, and the Desert Biome to the north. That the former 'Karoo Biome' of South Africa comprised two distinct biotic areas was recognised by Huntley (1984) and each was raised to full biome status by Rutherford & Westfall (1986). Their biotic division corresponded to the greater proportion of winter rainfall in the Succulent Karoo and the greater proportion of summer rainfall in the Nama-Karoo. This general association with the continuous variable of rainfall seasonality also accords with gradients between the two biomes which our demarcating lines on the map do not reflect. Where soil types are distinct, biome boundaries can be distinct. This is obvious especially in the case of SKr 19 Aggeneys Gravel Vygieveld and SKr 18 Bushmanland Inselberg Shrubland embedded within the NKb 3 Bushmanland Arid Grassland (Nama-Karoo).

Globally there are few other places that can claim to be as biologically distinct as the Succulent Karoo Biome. Unrivalled in its status as the world's only entirely arid region diversity hotspot (Mittermeier et al. 2000, Myers et al. 2000), this biome experienced numerous adaptive radiations and associated endemism for a wide range of faunal and floral groups. Worldwide, four geographically remote regions have mediterranean-type climatic regimes with transitions to desert environments like that of the Succulent Karoo (Cowling et al. 1996). These occur in Western USA & Baja California, Central Chile, the Mediterranean Basin and Western Australia. Floristically, however, none of these deserts is dominated by dwarf leaf-succulent shrubs, making the Succulent Karoo quite unusual among winter-rainfall deserts. The winter-rainfall Mojave Desert and western Sonoran Desert of California and Baja California as well as parts of the winter-rainfall Atacama Desert of Chile have vegetation that

boasts an abundance of succulents (mostly stem-succulent cacti and leaf-succulent *Yucca*). The mediterranean/desert transition zone in Western Australia is virtually nonexistent, as the transition to summer rainfall is abrupt in this area. Finally, the winter-rainfall deserts of the Mediterranean Basin (e.g. Negev Desert) do not have an equivalent succulent flora, and are largely dominated by annual species. Esler & Rundel (1999) suggest that it is the unique seasonal and interannual rainfall reliability of the Succulent Karoo that sets it apart from other mediterranean-type deserts.

2. Major Physical Environmental Features

2.1 Climate

The Succulent Karoo is a semidesert region with a strong maritime influence characterised by an even, mild climate. Most of the biome falls within a typical unimodal winter-rainfall region (Namaqualand and the western Great Escarpment), while the greater Little Karoo region (encompassing vegetation units SKv 8 to 14) shows either all-year-round precipitation (SKv 8 to 11) or bimodal (equinoctial) precipitation regimes (SKv 12 to 14). The features of the latter regime can also be seen in the climate data for the Roggeveld Karoo (SKt 3)—a unit with a transitional character between the Succulent Karoo and Nama-Karoo Biomes (Figure 5.2). The Summer Aridity Index (SAI) is greater than 4.8 (Rutherford & Westfall 1986).

The Mean Annual Precipitation (MAP) for most of the units is between 100 and 200 mm. Some of the Richtersveld units (SKr) adjoining the Namib and Gariep Deserts as well as part of the Tanqua Karoo (SKv 5) and part of some west coast units, for example Namaqualand Coastal Duneveld (SKs 8), have a MAP below 100 mm, while most of the valley rainshadow units (Little Karoo) have a precipitation higher than 200 mm; the unit with the highest precipitation is Robertson Karoo (SKv 7), reaching almost 300 mm. The overall biome average is about 170 mm. A distinctive characteristic of the rainfall regime is its relatively high predictability (Hoffman & Cowling 1987) and prolonged droughts are very rare (Desmet & Cowling 1999). This element of climatic stability (pronounced also when Succulent Karoo is compared to analogous winter-rainfall semideserts of the world) plays an important role in fostering and preserving the high species diversity of the biome (Cowling et al. 1999). Rainfall is usually cyclonic—derived from depressions associated with the circumpolar westerly belt (Schulze & McGee 1978). Its kinetic energy is lower for the biome as a whole compared to the other biomes and the rain events tend to be widespread, mostly gentle showers—while much of the rainfall of the Nama-Karoo is highly localised, intense and short thunderstorms (Schulze 1997). Hailstorms are rare in the Succulent Karoo. Milton & Collins (1989) pointed out that the frequency of hail events can account for the richness of the succulent flora (succulents being extremely sensitive to mechanical damage). Along the Namaqualand coast and along the west-facing escarpment, the low rainfall is supplemented by frequent coastal fog. High air humidity in places (especially) along the coast and relatively cool nocturnal temperatures generate copious dewfalls which may occur all year round (Von Willert et al. 1990, 1992, Cowling et al. 1999, Desmet & Cowling 1999).

The overall Mean Annual Temperature (MAT) of 16.8°C for the biome indicates the warm-temperate climate regime. Indeed most of the vegetation units show a MAT ranging between 16°C and 18°C, with notable exceptions of some SKt units, including the high elevation Roggeveld Karoo with a MAT of only 14.5°C. The occurrence of frost is apparently a function of the distance from the sea (continentality) and altitude. In the low-lying coastal regions (Sandveld, western Richtersveld and Knersvlakte) frost is a rare phenomenon, while along the Namaqualand escarpment frost may occur 7 to 13 days per year. The vegetation units found in deep valleys surrounded by high mountain ranges can have frost most often (mainly due to thermal inversion)—15 to 30 days per year. The units found on the continental plateau beyond the escarpment also have a high incidence of frost (20–25 days per year), with SKt 3 Roggeveld Karoo again a notable exception reaching almost 60 frost days per year. Absolute temperature values greater than 44°C have been recorded in low-lying coastal regions (e.g. west coast) that experience catabatically warmed berg winds that descend from the interior plateaus of the country (Rutherford & Westfall 1986). A characteristic of autumn, these conditions can persist for several days and are suspected to have a profound effect on the vegetation (Von Willert et al. 1990, 1992, Cowling et al. 1999, Rossa & Von Willert 1999).

The biome has the shortest summers with duration of less than 198 days (Schulze 1980). Incoming radiation in summer ranges from 270–280 J m^{-2} day^{-1}, which is higher than that for the other biomes according to Schulze & McGee (1978).

2.2 Geology

The Succulent Karoo Biome covers a large area characterised by complex geology. The northernmost parts of the biome occur on rocks of the Richtersveld Terrane, the Namaqua-Natal Metamorphic Belt and the Gariep Metamorphic Belt. These different geological areas became juxtaposed during two orogenic events of supercontinent assembly and break-up (Hoffman 1999), namely the Kibaran (during which the supercontinent Rodinia was assembled) and the Pan-African (during which the supercontinent Gondwana was assembled).

The volcanic and sedimentary rocks of the Bushmanland Terrane were probably deposited on older crust very similar to that found in the Richtersveld Terrane. During the Namaqua-Natal metamorphism (approximately 1 100 mya), these rocks

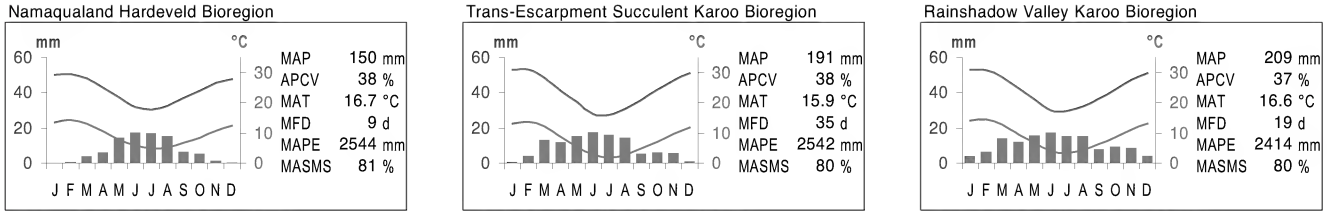


Figure 5.2 Climate diagrams of selected bioregion units. Blue bars show the median monthly precipitation. The upper and lower red lines show the mean daily maximum and minimum temperature respectively. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days (days when screen temperature was below 0°C); MAPE: Mean Annual Potential Evaporation; MASMS: Mean Annual Soil Moisture Stress (% of days when evaporative demand was more than double the soil moisture supply).

became strongly deformed except a small area at the core of the Richtersveld, which escaped the event (Thomas et al. 1994). In northern Bushmanland the characteristic landscape of inselbergs on a vast peneplain is the result of extensive erosion since the drifting apart of Gondwana.

Voluminous magmatic material is found in these two terranes, including the Vioolsdrif Suite in the Richtersveld and the younger granites and gneisses of Bushmanland, which stretch as far as Vanrhynsdorp. The intrusive rocks of the Bushmanland Terrane include older gneisses that formed well before the metamorphic event and include examples such as the Kamieskroon Gneiss and those of the Stalhoek Complex. The younger group of intrusive rocks formed shortly before and during the event and include the Spektakel and Little Namaqualand Suites.

To the west of the Richtersveld and the Bushmanland Terranes lies the Gariep Metamorphic Belt which formed during the assembly of the supercontinent Gondwana. The belt hugs the northwestern coast of South Africa and formed approximately 500 mya (Frimmel 1995, Frimmel & Frank 1998). This Pan-African event was related to the Saldanian Orogeny in the Western Cape, which also included the formation of the Cape Granite Suite. The Kuboos-Bremen Suite represents a similar, but less extensive, suite of granitic rocks to the Cape Granite Suite that formed in relation to the Gariep Orogenesis. Part of this suite also intrudes the Richtersveld Terrane (Frimmel et al. 1996).

In conjunction with the Pan-African Orogenesis, Cambrian-aged sediments formed as a result of the erosion of the mountain chains that had formed. The Vanrhynsdorp Group, which includes the Knersvlakte Subgroup, is such an example. These sediments were formed in a fairly shallow water environment, and towards the south they are covered by the younger Cape Supergroup sedimentary rocks (Gresse & Germs 1993). The rocks of the Vanrhynsdorp Group are also covered in large parts by recent (Quaternary) alluvial deposits of sand and occasional calcretes. These, as well as the recent sediments covering large parts of the west coast, are the result of fluctuations in sea level in the recent past Rogers et al. (1990).

In the southwestern and southern Cape the geology is dominated by the Cape Fold Belt (as discussed in the Chapter on Fynbos Biome in this book). This mountainous area consists of thick packages of fairly monotonous sandstone separated by thinner shale bands that all form part of the Cape Supergroup. These sediments were deposited at a time when Gondwana was moving towards the South Pole. As the supercontinent was situated at these high latitudes, the glacial deposits of the Dwyka Formation were laid down, marking the start of the Karoo Supergroup sedimentation.

Succulent Karoo vegetation occurs predominantly on shale rocks in the southern and western Cape. The Bokkeveld Group of the Cape Supergroup is most dominant, with other rocks of the Supergroup playing a smaller role in certain areas. Examples of this abound: Succulent Karoo of the Western Little Karoo, the Little Karoo near Oudtshoorn as well as the vegetation further east towards Willowmore and Steytlerville occur mostly on these shales of the Cape Supergroup. Shales of the Ecca Group of the Karoo Supergroup also support Succulent Karoo. In the southern Cape they play a role in the northernmost parts such as around Laingsburg and Prince Albert. The Karoo rocks are dominant in the Tanqua Basin as well as on the escarpment and towards the interior. Both Cape and Karoo Supergroups are the underlying rocks of the Succulent Karoo in the Robertson area.

The geology of both the Tanqua Karoo and the surrounds of Laingsburg both feature the lower units of the Karoo Supergroup, with the Dwyka diamictites giving way to deep marine sediments that include regular occurrences of turbidite deposits. These deposits form in deep water by means of the deposition of material transported in channelised debris-flows that flow down and splay out on the ocean floor. Although the package of sediments in these two areas is similar, there is noticeably more folding in the Laingsburg area as a result of the formation of the Cape Fold Belt over 200 mya. This folding peters out towards the north where the remaining Karoo sediments are almost entirely flat.

The Tanqua Basin is surrounded in the south and west by mountains of the older Cape Supergroup quartzites and shales. Here, in the vicinity of the Tanqua Basin, the Succulent Karoo vegetation can even be found on these Cape Supergroup quartzites, such as those of the Nardouw and the Witteberg. To the east of the Tanqua Basin lies the escarpment built of younger rocks of the Karoo Supergroup, which become younger still towards the interior, with increasing elevation as one travels up through the Karoo Supergroup.

2.3 Soils

Pedogenic diversification is a hallmark of arid environments and is supposedly one of the major driving forces of diversification of flora and vegetation in these climatically extreme ecosystems. In an arid ecosystem such as the Succulent Karoo, the availability of water largely controls the type and functioning of the ecosystem. Since soil is the main body for collecting and storing rainwater or water accumulated from fog, the ways the soil intakes, translocates, stores and eventually loses water are of crucial ecological relevance. The soils of the Succulent Karoo possess special features which modify water infiltration, hydraulic conductivity, subsurface storage and water supply to plants. Unlike in higher-rainfall areas bordering on the Succulent Karoo in the south (Fynbos Biome), where leaching is a regular feature, the soils of the Karoo are generally well supplied with the most important macro- and micronutrients (Ellis 1988). The plethora of habitats encountered in the Succulent Karoo reflects differences in soil chemistry and fertility that play an important role in microscale vegetation patterning.

Information on the Karoo soils is limited to reconnaissance mapping of land types (Land Type Survey Staff 1987), a few unpublished irrigation soil-survey reports and a review paper by Watkeys (1999). The study by Ellis (1988) covered a wide area, and included almost all the areas classified as Succulent Karoo (excluding only the Robertson Karoo). A paper by Francis et al. (2006) serves as an important source of information featuring more recent pedogenic work.

The main broad physiographical (soil-landscape) regions of the Succulent Karoo Biome and surrounding areas are featured in Figure 5.3. The Namaqualand coast (soil-landscape regions A1 and A2) is about 30 km wide, a generally flat plain, consisting of sandy material of aeolian origin. The soils of the coastal area consist of deep, grey, calcareous sands adjacent to the coast, followed by an interrupted zone of yellow sands. The inland part of this region consists of deep, red, sandy (in some places calcareous) soils. Inland of the coastal area and stretching generally northwest-southeast, a hilly mountainous area (soil-landscape regions B1 and B2) is situated, forming part of the Great Escarpment—a region separating a higher and older inland area from a younger low-lying coastal region of southern Africa. On average, it is about 60 km wide and rises from 300 m above sea level to altitudes as high as 1 700 m in places. The dominant rock types are granite and gneiss and the soils are generally shallow, base-rich to calcareous, reddish coloured, with a hardpan (duripan) at shallow depth in the valleys. The escarpment forms a natural separation between

the coastal area and the high-altitude flat inland plateau to the east (soil-landscape regions E2 and E3). The soils of the Knersvlakte are generally shallow, base-rich to calcareous and reddish coloured, with a duripan occurring at a shallow depth from the soil surface. A large area of the soils of the high-altitude plateau to the east consists of shallow to moderately deep, reddish coloured base-rich sands on granite/gneiss parent material (soil-landscape region E2) and shallow calcareous loams with desert pavement on the surface, where shales form the parent material (soil-landscape region E3). Another important feature is the deep pre-weathering, which can be encountered in many places, usually with a silcrete or ferricrete capping still preserved.

From Calvinia to Sutherland, the Great Escarpment (soil-landscape region F1) underlain by shale with shallow, stony lithosols dominant, stretches in a more or less southerly direction, and then (east of Sutherland) changes its direction towards the east. To the south of the Great Escarpment, and running more or less parallel to it, the sandstone and quartzites of the Cape Fold Mountains support stony, shallow, acid, sandy soils. Some of these marginal (very dry) areas (such as Swartruggens on the eastern rim of the Tanqua Basin and the Doring River Valley) support Succulent Karoo vegetation. The soil-landscape regions C1 to C5 represent plains, hills and lowlands below the Great Escarpment. Irregular plains with parallel hills stretching east-west (mostly built of shales) and lowlands and mountains with moderate relief and shallow lithosols (soil-landscape region C1) occur southwest of the Great Escarpment. The soil-landscape region C2 is a low-relief plain situated immediately to the east of the C1 region. Large areas of deep unconsolidated alluvial and colluvial deposits form the parent material of the soils. To the south of the Cape Fold Belt mountains (G1), the Little Karoo shows similar physiography to the soil-landscape regions C1 and C2, with C3 (western section) corresponding to C1 and C4 (eastern section, especially around the town of Oudtshoorn) to C2. However, in both cases, occasional silcrete cappings (remnants of the African Surface I; Watkeys 1999), linked to the sandstone mountains, occur with red apedal soils on duripan on the lowlying parts of the landscape and on the plains. These silcrete cappings support very stony, sandy, acid soils. The soil-landscape region C5 is a lowland between the Great Escarpment and the Cape Fold Belt mountains stretching north-south (part of the soil-landscape region G2), with saline alluvial soils along the rivers and lithosols with a very prominent desert pavement on the surface dominant in the remainder of the area.

In terms of the World Reference Base for Soil Resources (FAO 2005), the main soil groups in the Succulent Karoo Biome include both zonal and azonal soil groups such as Leptosols, Fluvisols, Solonchaks, Solonetz, Gypsisols, Durisols, Calcisols and Arenosols. Examples of most of the World Reference Base descriptive soil qualifiers, such as alcalic, arenic, aridic, calcaric, calcic, carbonatic, chloridic, duric, gypsic, hyperochric, hydrophobic, puffic, salic, sodic, takyric and yermic are likely to be found as well. All the special features inherent in this terminology are of ecological significance, some of which are briefly discussed below.

Ellis (1988) defined the bleached orthic A horizon during his survey of the Karoo soils as a surface horizon with a lighter colour than the subsurface horizons. This horizon, very common in most soils of the Karoo, is structurally unstable and is characterised by changes to the thin layer of soil at the interface with the atmosphere (also called 'pedoderm' by Mills &

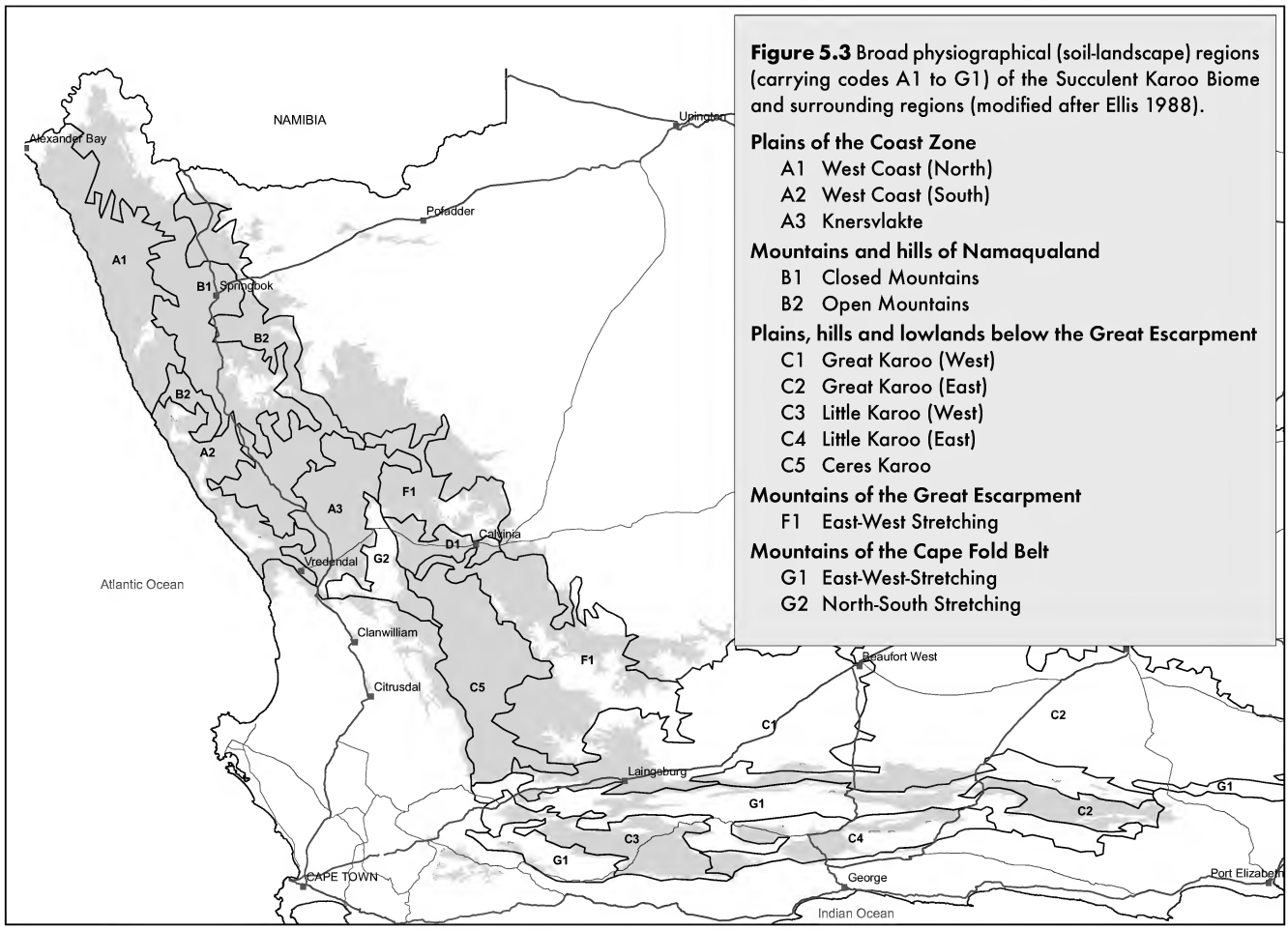


Figure 5.3 Broad physiographical (soil-landscape) regions (carrying codes A1 to G1) of the Succulent Karoo Biome and surrounding regions (modified after Ellis 1988).

Plains of the Coast Zone
- A1 West Coast (North)
- A2 West Coast (South)
- A3 Knersvlakte

Mountains and hills of Namaqualand
- B1 Closed Mountains
- B2 Open Mountains

Plains, hills and lowlands below the Great Escarpment
- C1 Great Karoo (West)
- C2 Great Karoo (East)
- C3 Little Karoo (West)
- C4 Little Karoo (East)
- C5 Ceres Karoo

Mountains of the Great Escarpment
- F1 East-West Stretching

Mountains of the Cape Fold Belt
- G1 East-West-Stretching
- G2 North-South Stretching

Fey 2004). Physical soil crusting (or soil sealing) might develop that may negatively influence aeration, germination, seedling emergence and root growth near the surface (Shainberg & Levy 1994). Crust formation promotes water runoff to accumulate in zones where water infiltration can cause deeper penetration, thereby stimulating deeper-rooted plants. On very sandy soils, especially along the Namaqualand coast, the surface soils show temporarily poor wettability, especially after long dry spells. The hydrophobic character is caused by certain organic compounds, such as waxes. Water infiltration is markedly impeded when dry soil is first wetted. This can cause localised ponding of water and subsequent deep infiltration. The water can then be utilised by deep-rooted plants, or more likely, by succulent plants with adapted root systems by upward transport of water vapour (Prinsloo 2005), or accumulate above a limiting layer such as a clay-pan.

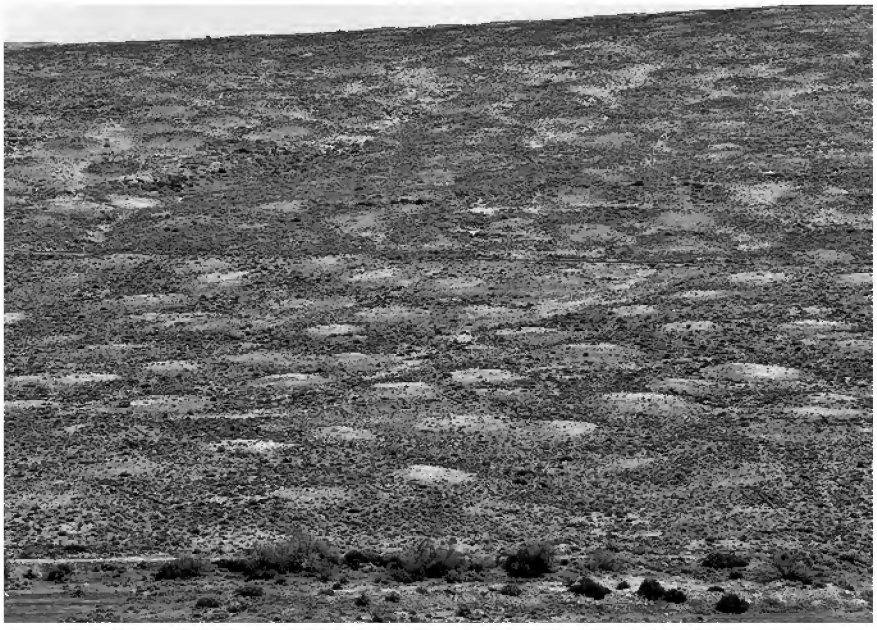
The surface of many of the soils as for instance on the Knersvlakte (A3), in the Western Little (Ladismith) Karoo (C3) and Tanqua (Ceres) Karoo (C5) is characterised by formation of desert pavement (surface layer of gravel and stones), in some cases so pronounced that the underlying fine earth material becomes fully covered. Such surfaces function as protective mulch, reducing raindrop impact and thereby preventing crust formation and enhancing water infiltration. Where milky quartz stones dominate, the reflective properties of the white desert pavement (known as quartz patches or quartz fields) influence the surface temperature of the soil, a factor which might have played a role in the structuring of plant communities on the quartz fields (Schmiedel & Jürgens 2004).

Subsurface soil properties that enhance water storage include textural water barriers (involving a very slight change in clay content in sands, influencing downward percolation of infiltrated rain water), cemented horizons such as dorbank (duripan), calcrete (petrocalcic) or sepiocrete (sepiolite-cemented hardpan) or clay pans, which directly influence downward movement of water. If over-saturation occurs in the layers above the hardpan, water may be stored for use by deep-rooted plants or, more likely (especially in the sands along the coast), by plants rooting close to the soil surface through upward transport of water vapour during cooling off of the surface soil layers during the night. This phenomenon is also known as nocturnal distillation (Prinsloo 2005).

In almost all the areas of the Succulent Karoo, large circular (approximately 30 m diameter), often slightly elevated (up to 1 m high) mounds are abundant. They are easily recognisable from a distance due to different coloration (resulting from different vegetation) against the surrounding background (Figure 5.4). These mounds are called 'heuweltjies' and their origin is ascribed to former activity of harvester termites (*Microhodotermes viator*). Although the conclusive evidence is still pending, heuweltjies are assumed to be ancient abandoned termitaria. Their abundance and presumed importance in ecological processes within the Succulent Karoo landscapes have generated much scientific interest (e.g. Lovegrove & Siegfried 1986, 1989, Midgley & Musil 1990, Esler & Cowling 1995, Laurie 2002, Ellis 2004). Most of the heuweltjies are characterised by a central petrocalcic (calcrete) to petroduric (duripan or dorbank) hardpan, with a petroduric horizon on a petrocalcic horizon towards the outer edge and occasionally also in the surrounding intermound areas. The mounds are virtually absent on base-poor parent material (e.g. sandstone). In a study by Ellis (2004) the pedoderm (0–10 mm surface horizon) of 18 representative heuweltjies was sampled from Springbok in the north to Oudtshoorn in the east. Soils on the heuweltjies are more fertile (average P content for topsoil horizons = 50 mg/kg) than between heuweltjies (P = 2 mg/kg). Most of the soil located near the centre of the heuweltjies tested positive for free lime and had a higher pH than the soil on the periphery of the heuweltjies. The combination of a higher fertility and differences in soil physical properties and of relief on a micro scale (influencing available water), is seen as the reason for the strong differences in biodiversity that occur on and between heuweltjies. Heuweltjies are also common in especially Namaqualand where they cover as much as 25% of the landscape in places.

3. Biogeography and Diversity Patterns

This desert shrubland largely comprises the winter-rainfall arid zone of southern Africa and is classified by phytogeographers as the Succulent Karoo Floristic Region (Jürgens 1991). This relatively new phytochorion formed a part of the broadly conceived Karoo-Namib (Floristic) Region of Werger (1978, 1986) called Karoo-Namib Regional Centre of Endemism (White 1983) until recently.



K. Phillips

Figure 5.4 SKn 4 Namaqualand Heuweltjieveld: Complex of ancient termitaria (heuweltjies) scattered across lower slopes of granite glacis and supporting succulent dwarf shrubland, near Garies in Namaqualand (Northern Cape).

Jürgens (1991) has subdivided the Succulent Karoo Region into two domains. The Namaqualand-Namib Domain, broadly coinciding with the magisterial district of Namaqualand, is situated in the strongly winter-rainfall region of the Cape West Coast and Namibia. Here, fog and dew supplement the mean annual rainfall of 150 mm, which varies 20-fold across the domain from approximately 20 mm in the northwest to 400 mm in the central granite uplands (Desmet & Cowling 1999). Interestingly, some of the highest temperatures in this domain are recorded in winter, when hot, dry föhn-like berg winds descend towards the coast from the central uplands of the subcontinent (Desmet & Cowling 1999). These winds have the potential to influence population dynamics and turnover

dramatically, but evidence in this regard is scant. In contrast, the Southern Karoo Domain has rainfall peaks in spring and autumn. Here the mean annual rainfall, ranging from 50 mm to 250 mm, is associated with post-frontal advection of moist air across the warm Indian Ocean. While the temporal patterns of rainfall differ between the two domains, rainfall predictability is a common feature, and one that sets the Succulent Karoo apart from other deserts (Esler et al. 1999a). At a biome scale, the length and temperature of the growing season demarcates the Succulent Karoo (short and cool) from adjacent Fynbos (long and cool) and Nama-Karoo (short and warm) (Ellery et al. 1991). In addition, geology and soils play some role in distinguishing biome boundaries. For example, Succulent Karoo soils are largely fine-grained, less leached (due to aridity) and have a higher pH (>7) and cation exchange capacity than fynbos soils (Ellis & Lambrechts 1986).

Mole rats, lizards, tortoises and a variety of invertebrates, including monkey beetles, scorpions, bee flies, bees and masarid and vespid wasps (Vernon 1999), all have concentrations of diversity and endemism in the Succulent Karoo Biome. Botanically, it is compositionally fascinating (Cowling et al. 1994) and singularly rich (Cowling et al. 1998), being home to 6 356 species of vascular plants in 1 002 genera and 168 families (Driver et al. 2003). Some 26% (1 630) of the species are strict endemics and 14% (905) are near endemics that have the centre of their distribution in this biome (Driver et al. 2003); 17% (Driver et al. 2003) are listed as Red Data species (International Union for Conservation of Nature 1994). Most of the 80 genera endemic to the biome are either succulents or geophytes (Driver & Maze 2002, Driver et al. 2003).

The high diversity of dwarf leaf-succulent shrubs (1 700 species; Driver et al. 2003) is the biome's most distinctive character (Figure 5.5). The 'vygies' or members of the family Aizoaceae (Bittrich & Hartmann 1988; formerly Mesembryanthemaceae) are particularly prominent among this group, but the 'spurges' or Euphorbiaceae, the 'stone crops' or Crassulaceae and succulent members of the Asteraceae, Iridaceae and Hyacinthaceae also deserve special mention (Hilton-Taylor 1996, Milton et al. 1997, Cowling & Hilton-Taylor 1999). Approximately 16% (1 589 species; Driver et al. 2003) of the world's estimated 10 000 succulent species occur here (Van Jaarsveld 1987). Perennials display high levels of alpha (Cowling et al. 1998), beta and gamma diversity (Cowling et al. 1994). Geophytes are another successful growth form (Figure 5.6), comprising 18% of the flora (Driver et al. 2003). In terms of abundance and diversity, they are as successful in the Succulent Karoo Biome as they are in the Fynbos Biome (Hilton-Taylor 1996, Esler & Rundel 1998, Cowling et al. 1999, Esler et al. 1999b). Finally, while there is nothing unique about diversity of annual plants and their proportional representation in the flora of the Succulent Karoo (390 species; Driver et al. 2003), the relatively predictable and often extravagant mass spring flower displays (Figure 5.7) are worth noting (Struck 1994, Cowling et al. 1999, Van Rooyen 1999).

4. Ecological and Evolutionary Driving Forces

What factors have led to the diversification of such a variety of plant and animal lineages in this biome? Many of the biologically unique features of the Succulent Karoo Biome have been attributed to its climatic conditions (Cowling et al. 1999, Cowling & Pierce 1999). Two key aspects of the climate combine to produce a unique selective regime. First is the highly effective and relatively predictable seasonal rainfall associated with 'cold fronts' and caused by major disturbances in the circumpolar westerly air stream (Desmet & Cowling 1999). Second are the relatively moderate winters and early spring temperatures due to the ameliorating influence of the Atlantic Ocean and a consequence of a 'peninsula' effect of the continent (more typical of the Namaqualand-Namib Domain). The onset of the winter-rainfall regime approximately 5 mya is believed to have triggered the remarkably rapid diversification in at least one key family, the Aizoaceae (Klak et al. 2004).

Some authors suggest that climatic predictability has allowed for plant-pollinator specialisation to occur, since synchronisation in flowering and invertebrate pollinator emergence is virtually guaranteed (Esler 1999, Colville et al. 2002). Others have developed a conceptual model that suggests that the unique selective regime of the Succulent Karoo has had repercussions for pattern and process across different levels of organisation and has ultimately led to species-rich communities (Cowling et al. 1999, Esler et al. 1999a, b). This model highlights the observation that the ratio of functional diversity to species diversity in Succulent Karoo plant communities is generally relatively low (Cowling et al. 1994). While many contemporary models explaining plant structure in desert ecosystems emphasise the role of competition and consequent niche differentiation, this model explicitly plays down competition while emphasising the role of positive interactions (Eccles 2000, Eccles et al. 1999, 2001). Furthermore, the model suggests that the high levels of determinism suggested for other desert ecosystems (e.g. Aguiar & Sala 1999) may have been overshadowed by the structural homogeneity of the species and the rapid population turnover rates. The latter is associated with the fact that succulents, although highly successful in predictable rainfall environments, with their limited storage capacity (Von Willert et al. 1992) and shallow root systems (Esler & Rundel 1999) are also highly sensitive to periodic drought. The suggestion is that stochasticity, both spatial and temporal, as in the case of diverse tropical forests (Hubbell & Foster 1986) may be central to the coexistence of species in this unusually diverse system (even within the broader context of predictable rainfall). Although more research is needed to test and refine the model, several areas of research findings have proved consistent with the model predictions (Cowling et al. 1999).

For certain lineages, speciation may have been fuelled by the combination of life-history characters such as limited gene dispersal, short generation times and nonoverlapping generations as well as periodic droughts that cause high turnover and fragmentation in populations (Cowling et al. 1998, Cowling & Pierce 1999, Colville et al. 2002). For example, these elements all coincide in the Aizoaceae, southern Africa's largest succulent plant family (Smith et al. 1997), which has undergone a remarkable and rapid explosive diversification in the Succulent Karoo (Ihlenfeldt 1994, Klak et al. 2004). This family of mostly obligate out-crossers is pollinated by a variety of insects, including monkey beetles that travel short distances (Colville et al. 2002). Most Aizoaceae have relatively short generation times (5–15 years), as do their pollinators. Seeds are retained in canopy-stored capsules (Esler & Cowling 1995) and are dispersed over short distances during rainfall events (Garside & Lockyer 1930, Lockyer 1932). Finally, Jürgens et al. (1999) reported that the turnover of Aizoaceae over 15 years of monitoring was remarkably high for perennials in an arid system. Disturbance, in the form of short-term, periodic droughts, has a return time in the order of 1–2 decades in this system (Midgley et al. 2001), although prolonged droughts are rare.

Jansson & Dynesius (2002) and Jansson (2003) theorised that limited Pleistocene climatic change in diverse regions of the world, including southwestern South Africa, may have facili-

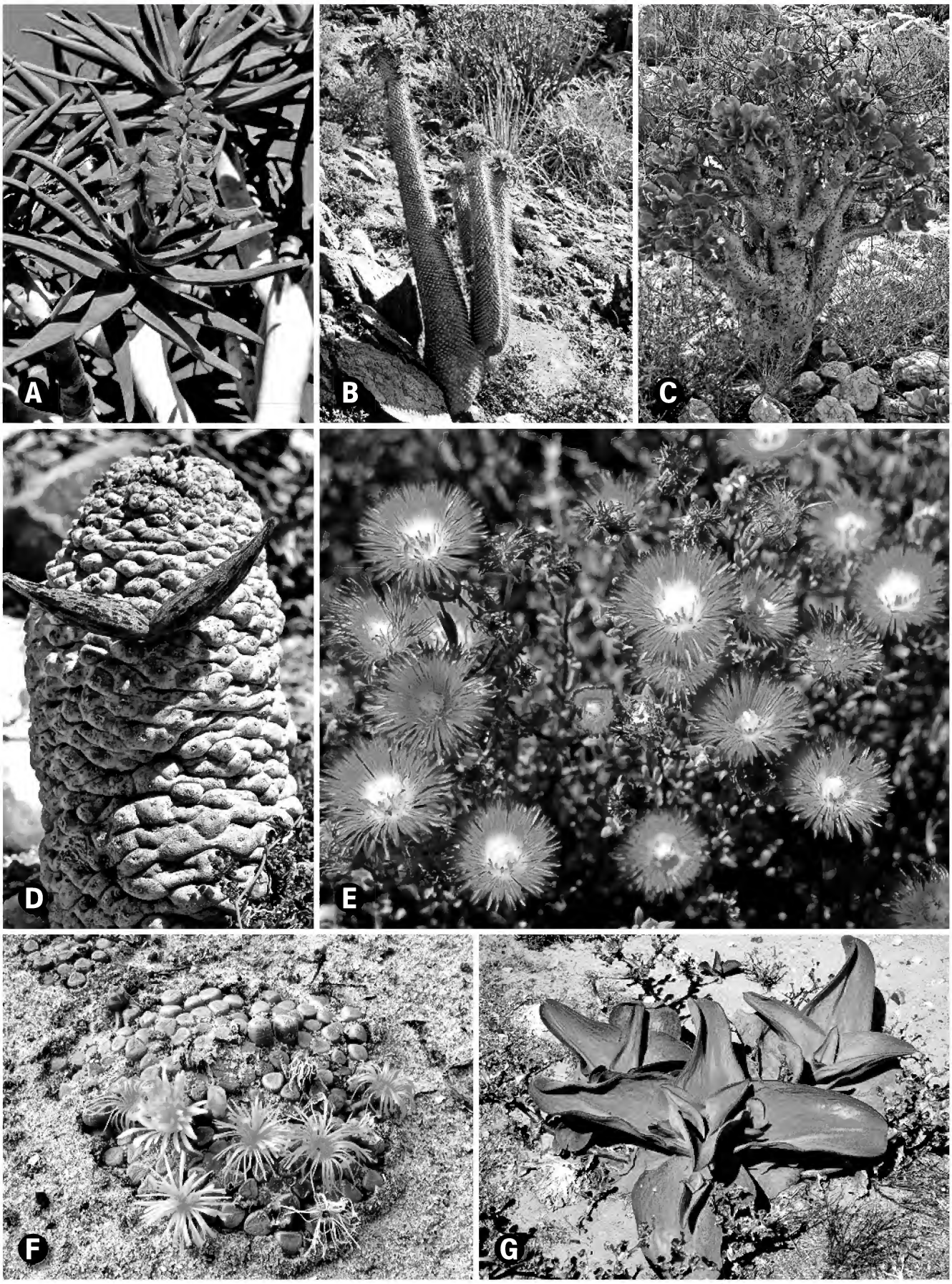


Figure 5.5 Assorted succulent plants from the Succulent Karoo. A: kokerboom–*Aloe dichotoma* var. *dichotoma* (Asphodelaceae); B: halfmens –*Pachypodium namaquanum* (Apocynaceae); C: botterboom–*Tylecodon paniculatus* (Crassulaceae); D: *Larryleachia perlata* (Apocynaceae); E: *Drosanthemum bicolor* (Aizoaceae); F: *Fenestraria rhopalophylla* subsp. *aurantiaca* (Aizoaceae); G: *Mesembryanthemum barklyi* (Aizoaceae). Photographers: L. Mucina (A–C, F–G), K. Phillips (D), J.C. Manning (E).

tated the persistence of lineages through extreme Pleistocene climatic oscillations that caused significant extinctions in many parts of the world. In contrast, Midgley et al. (2001) proposed that climatic oscillations of intermediate amplitudes over the past two million (+) years may have favoured vicariance and allopatric speciation in the Succulent Karoo Biome. They suggest that floral diversity may have arisen by a dynamic pattern of speciation, rather than by a passive accumulation of species in response to smaller climatic oscillations. Centres of endemism, such as the Gariep CE and the Knersvlakte CE (Van Wyk & Smith 2001), are viewed as landscape-scale glacial refugia (Jürgens 1997, Midgley et al. 2001). Interestingly, climatic oscillations have also been proposed as an explanation for vicariance/population differences among rock-dwelling vertebrates (Matthee & Flemming 2002).

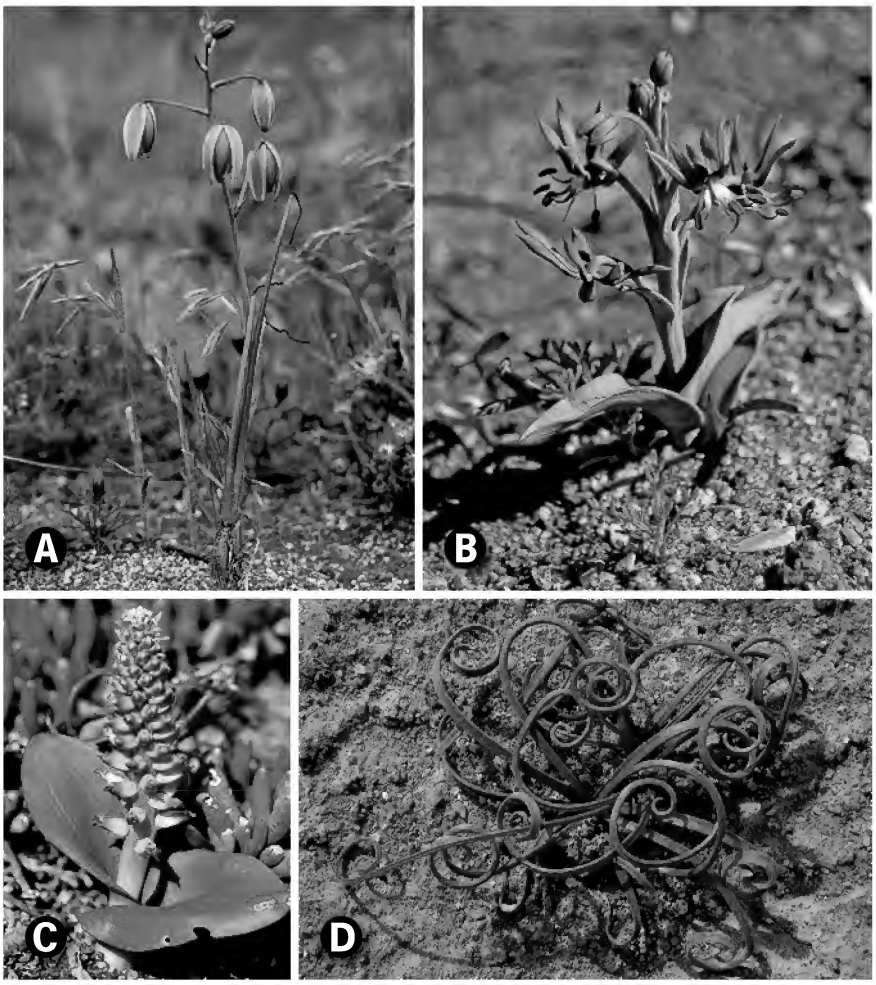


Figure 5.6 Selection of geophytes from the Succulent Karoo. A: *Albuca cooperi* (Hyacinthaceae); B: *Ornithoglossum vulgare* (Colchicaceae); C: *Lachenalia carnosa* (Hyacinthaceae); D: unknown bulbous plant with typical cork-screw leaves. Photographers: L. Mucina (A–C), M. Pfosser (D).

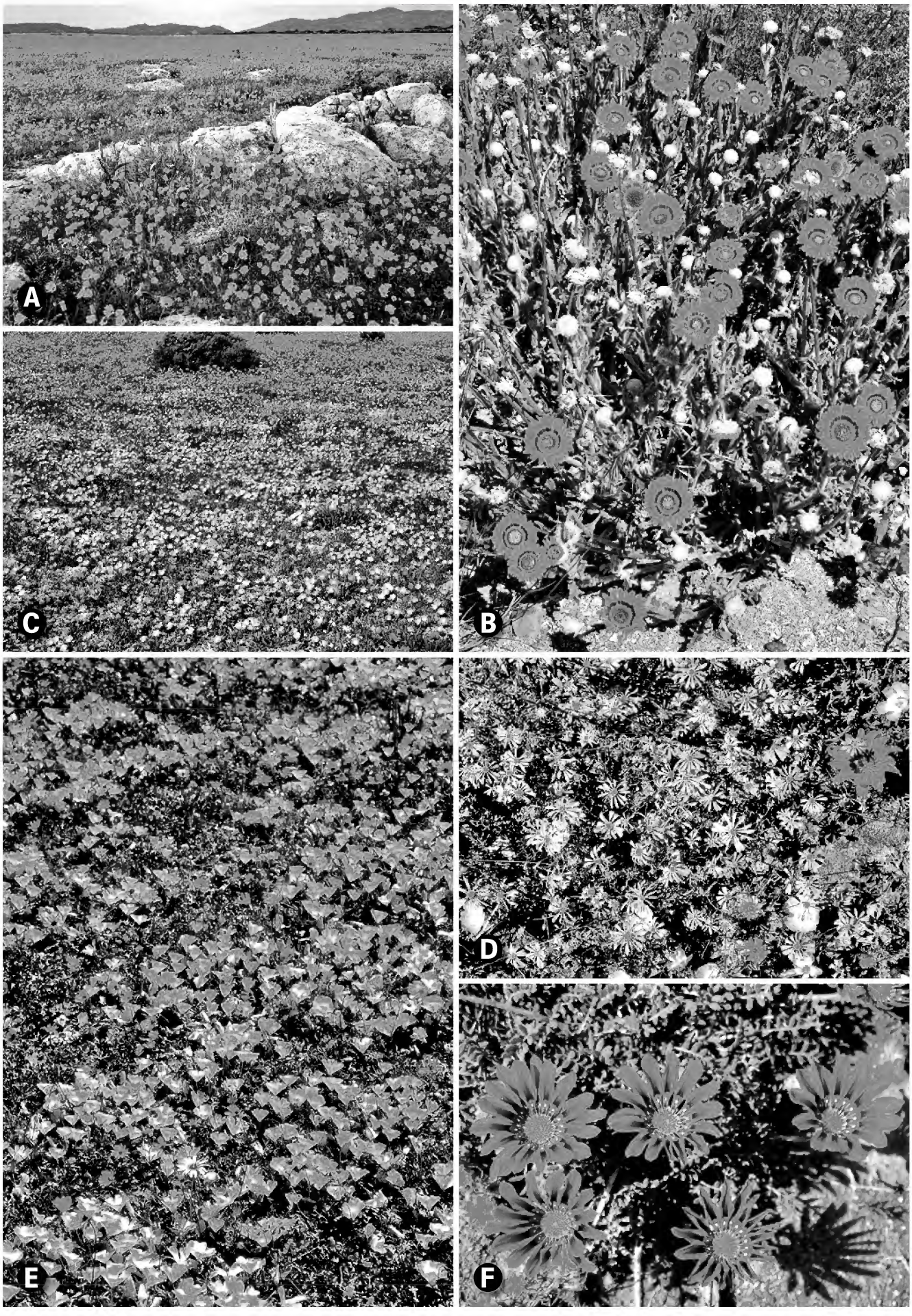
Physical heterogeneity associated with soils may have also played a role in diversification, and has certainly been invoked to explain patterns of diversity at a landscape (Cowling & Hilton-Taylor 1999) and local scale (Schmiedel & Jürgens 1999). The geology and consequently soils of the Succulent Karoo Biome are extremely complex (Meadows & Watkeys 1999, Watkeys 1999). In the northwest, the mountainous Richtersveld region comprises a varied sequence of pre-Gondwanan rocks, extensively intruded by granite and gneiss of the Namaqualand Metamorphic Province. The Richtersveld, with several local endemics, forms the core of the Gariep CE (Van Wyk & Smith 2001). The height and orientation of the mountains (to intercept moisture) as well as their diverse geology have been invoked to explain the high levels of succulent diversity and endemism in this region (Van Wyk & Smith 2001). Erosion of the Namaqualand metamorphic rocks produced the dramatic 'koppie' landscapes to the south in the escarpment region, known locally as the Hardeveld. Approximately 900–500 mya, sedimentary rocks of the Gariep, Numees and Nama Formations were laid down in a rift basin coinciding with the west coast region, and forming the floor of the palaeo-Orange River delta. Weathering of quartz veins from these formations resulted in the characteristic quartz patches of the Knersvlakte. In this edaphically variable region of floristic endemism (Knersvlakte Centre; Van Wyk & Smith 2001), differences in soil type can result in sharp species turnover within a few metres (Jürgens 1986). The Knersvlakte supports 52 species adapted to quartz-fields of which 39 are endemic to the region (Schmiedel & Jürgens 1999). Quartz patches (Figure 5.8) also occur in several other regions of the current Succulent Karoo Biome (Schmiedel 2002b, 2004) and contribute notably to increased local species and generic endemism.

Apart from the well-known climatic impact on the coastal biota (see the chapter on Desert in this book), the Benguela Current is also responsible for wind-blown 'sand movement corridors' (Driver et al. 2003) that are of marine origin and consist of an array of sediment types ranging from weathered fine-grained deposits of the late Tertiary to recent white sands along the coast. These corridors are dynamic systems that provide a range of key habitats for both flora and fauna (Desmet 1996) and at times act as important barriers to movement of organisms. Rocks in the Southern Karoo Domain are essentially younger than those of the Namaqualand-Namib Domain. This Domain is largely located on the level plains and gently rolling hills in the valleys between the east-west ranges of the Cape Fold Belt. A mosaic of rock strata comprising sediments of the Cape Supergroup and Karoo Sequence (conglomerates, shales, limestone, mudstones, siltstones and sandstones) is found here (Meadows & Watkeys 1999).

In contrast to edaphic variability, topographic variation does not appear to hold the key to explaining extreme richness in this biome, since although it is topographically diverse, it does not approach the altitudinal range and habitat variability associated with the mountains of the Cape Fold Belt (Cowling et al. 1997).

5. Status

A mere 5.8% or 6 500 km^2 of the Succulent Karoo Biome is formally protected in statutory and nonstatutory reserves (Driver et al. 2003). This area substantially under-represents the diversity associated with the biome, and a recent conservation planning exercise (Driver et al. 2003) highlighted the fact that the current protected area system does not incorporate key ecological processes and evolutionary biodiversity drivers. These include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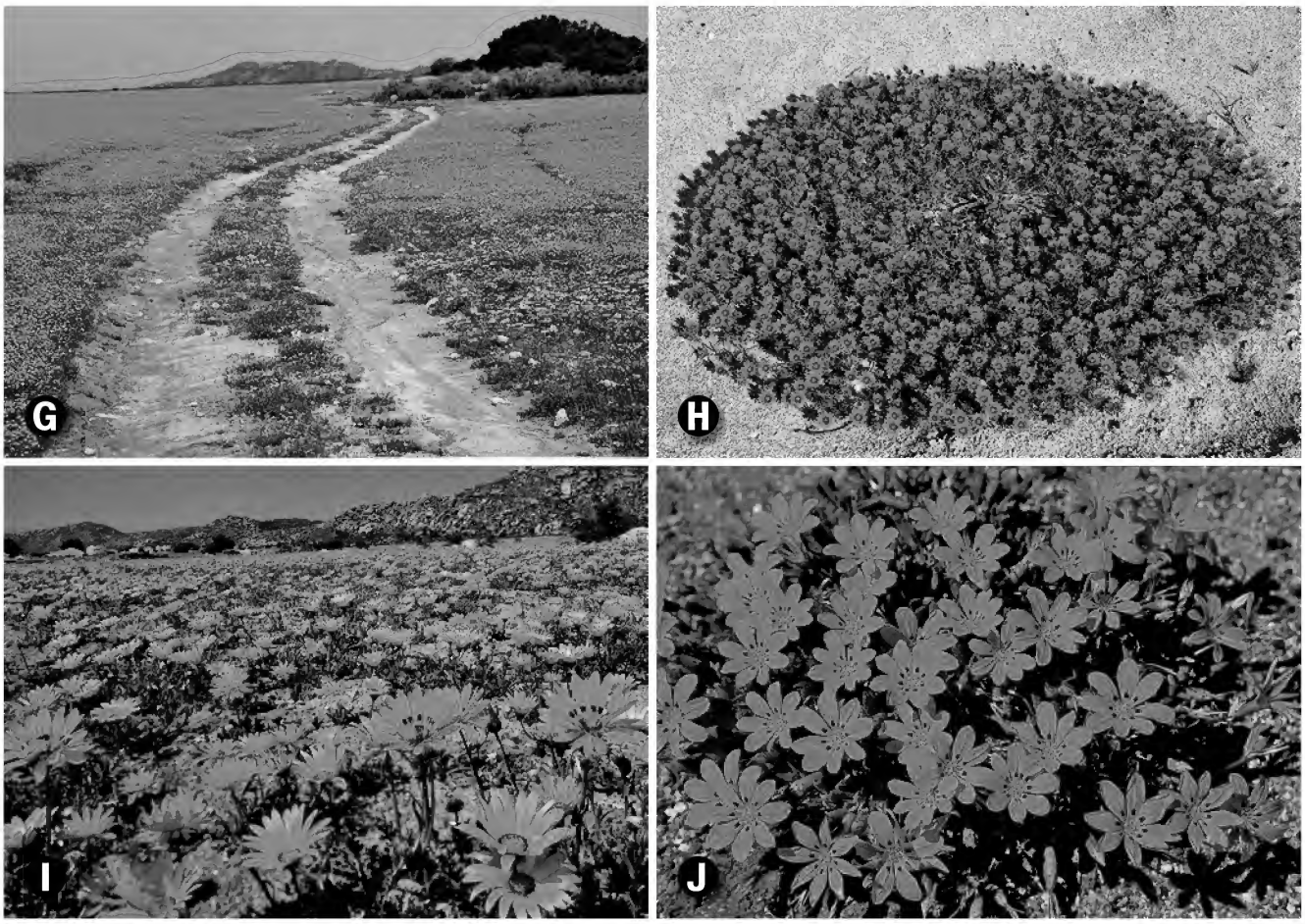


Figure 5.7 Spectacular Namaqualand spring flower displays. A: *Ursinia cakilefolia* (Asteraceae) in the Skilpad Flower Reserve (today part of Namaqua National Park), west of Kamieskroon; B: *Arctotis fastuosa* (Asteraceae) on disturbed shale substrate on the Farm Ezelsfontein in the Spektakelberg Pass (west of Springbok); C: spring flower display of *Grielum humifusum* (yellow), *Felicia namaquana* (blue) and *Arctotis fastuosa* (orange) in an old field in the Goegap Nature Reserve near Springbok; D: a small population of *Felicia* species; E: mass flowering of *Grielum humifusum* (Neuradaceae) on an abandoned pasture; F: *Gazania leiopoda* on the Farm Modderfontein near Kamieskroon; G: *Cotula barbata* and *Arctotheca calendula* (both Asteraceae) on old fields of the Farm Modderfontein east of Kamieskroon; H: a local form of *Gorteria diffusa* (Asteraceae) from the Spektakelberg Pass; I: *Arctotis* species (Asteraceae); J: *Gazania lichtensteinii* (Asteraceae), one of the most common daisies in Namaqualand. Photographers: K. Phillips (A, I), L. Mucina (B–H, J).

riverine and sand movement corridors, quartz patches, edaphic interfaces, climatic and upland-lowland gradients.

Outside formal reserves, land use is primarily focused on agriculture, with livestock grazing as a dominant land use in 90% of the region (Driver et al. 2003). Although grazing is a form of land use that is theoretically compatible with biodiversity conservation, overgrazing has had its consequences (Todd & Hoffman 1999, Archer 2000). Before widespread human settlement by Europeans in the 18th and 19th centuries, indigenous antelope such as springbok (*Antidorcas marsupialis*), gemsbok (*Oryx gazella*), black wildebeest (*Connochaetes gnou*), quagga (*Equus quagga*) and red hartebeest (*Alcelaphus buselaphus*) would have migrated across the landscape in search of grazing (Dean & Milton 1999a), no doubt having an overall positive influence on biodiversity. However, fences, permanent watering points and high stocking densities of domestic livestock and ostriches have almost certainly led to degradation in places (Hoffman et al. 1999). Loss of vegetation cover, seed banks and soil quality may have had dire consequences for biodiversity in general and strategic rehabilitation interventions in local areas may be required.

Mining, although locally devastating, may have ironically protected the Succulent Karoo Biome from massive transformation due to development and overgrazing. This is because many mines own large buffer areas of land, generally in an excellent condition. For example, in the Alexcor concession, comprising about 800 km^2 between Port Nolloth and Alexander Bay, only about 10% of the land is affected as a result of open-cast diamond mining (Desmet 1996).

Only about 5% of the geographic area of the Succulent Karoo Biome has been irreversibly transformed (Driver et al. 2003), providing a relatively good situation for conservation planning, since there are still options for meeting conservation targets for most biodiversity features. The unique botanical diversity of the region has been a major advantage, as it has provided solid justification for conservation planning based on plant diversity.

6. Threats

Human population pressures present huge challenges to the future existence of the Succulent Karoo. Climate change has been identified as one of the most significant threats to the environment (Intergovernmental Panel on Climate Change 1996) and global temperatures may have already increased by about 0.5°C over the last century. For sub-Saharan Africa, Global Circulation Models predict an increase of 1–3°C over

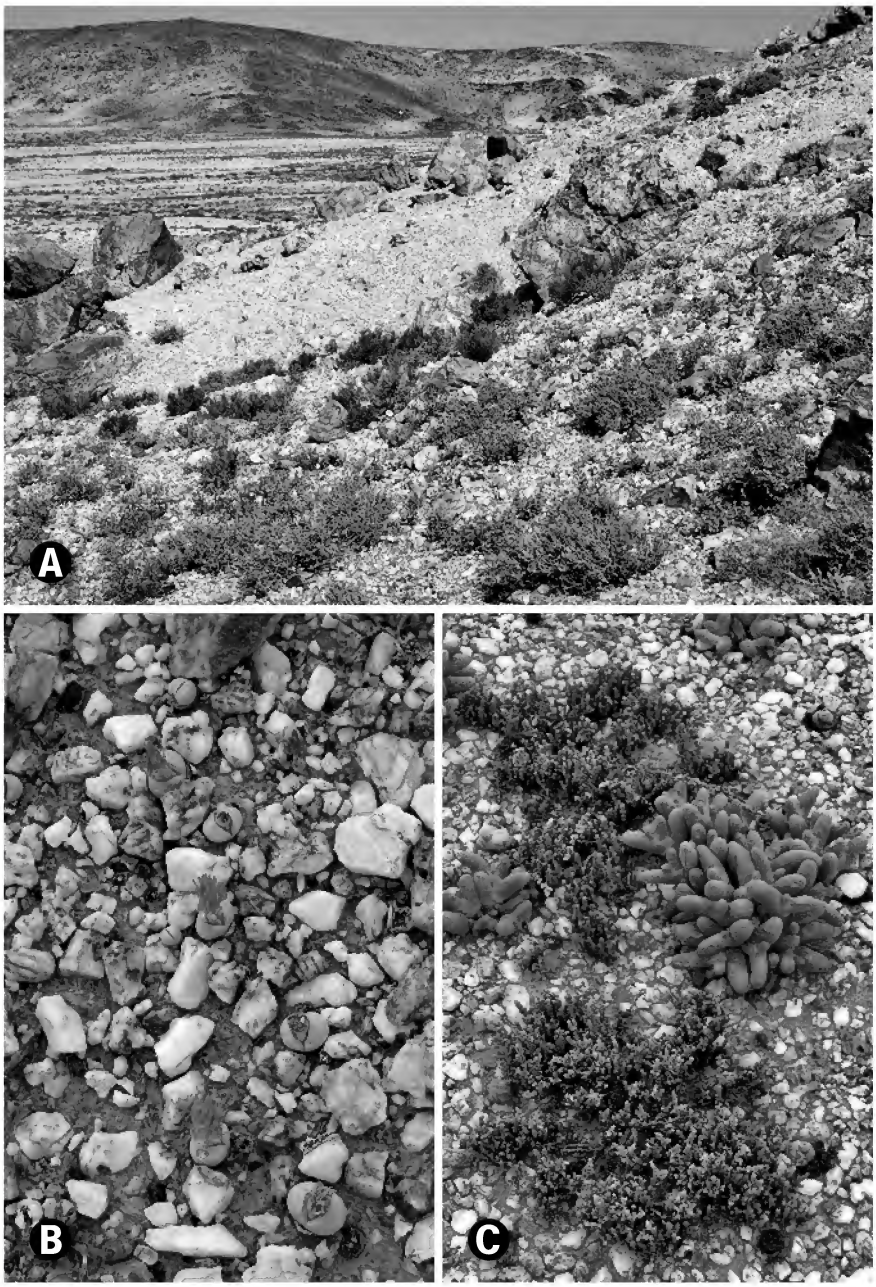


Figure 5.8 A: quartz-dominated slopes of hills bordering on the Knersvlakte (southern Namaqualand, Western Cape). B: quartz patch with flowering *Argyroderma delaetii* (Aizoaceae) near Rooiberg (Knersvlakte). C: dwarf stem succulent *Dactylopsis digitata* (Aizoaceae) and sprawling individuals of an undescribed species of *Salsola* (Chenopodiaceae) on the Farm Quaggaskop (northwest of Vanrhynsdorp, Western Cape). Photographer: L. Mucina.

the next 50 years (Anonymous 1998) and rainfall is expected to decrease (Ellery et al. 1991, World Wildlife Fund 2001). Predictions for the Succulent Karoo are somewhat uncertain, but shifting climate patterns could result in a change in rainfall seasonality, with a significant portion of the current winter rainfall falling in summer (Bond 1997).

Bioclimatic models at the biome scale have indicated that climate change will be devastating to the Succulent Karoo if the region becomes any drier (World Wildlife Fund 2001). The current bioclimatic envelope could literally 'disappear' from its current range by 2050 (Midgley et al. 2002). Population-level data on species at the edge of their distributions are needed to illustrate the potentially dire consequences of climate change. For example, populations of arborescent succulents are on the decline at the extremes of their distributions in the Succulent Karoo (Jürgens 1997, Foden 2002), suggesting that climate change may already be having a negative effect.

Early supporting evidence from field experiments (Musil et al. 2005) underscores the lethal impact to endemic quartz-field succulents of warming levels projected for the end of this century. Interestingly, preliminary data from reciprocal transplants of Succulent Karoo Aizoaceae seedlings (Agenbag et al. 2004) show their improved survival and growth under typically cooler and wetter Fynbos-like climatic conditions—suggesting persistence and even greater success of these forms under the cooler and wetter conditions of glacial stages during the Pleistocene. This preliminary result is wholly consistent with the apparent Pleistocene diversification of selected lineages in the Aizoaceae (Klak et al. 2004). Taken together, these findings highlight in an evolutionary context the potentially disastrous effects of warming beyond levels seen at any time during the climatic regime of the Pleistocene.

Changing climate as well as other aspects of global change such as fragmentation, habitat alteration and species invasions may also result in disruptions to pollinator groups, with potentially serious ecological consequences. This is especially so, since many plants with relatively short generation time rely on seedling recruitment for persistence.

Mining, although an important economic driver in the region, still constitutes a significant threat to biodiversity. The primary diamond mining impact is from prospecting through trench excavation, and overburden stripping in larger areas to reach the diamond-bearing gravels. Of key concern is that specialised habitats such as riverine flood plains and coastal terraces are targeted. In many cases, these are the areas considered as key habitats for ecological processes (Driver et al. 2003). New markets and discoveries of metals such as titanium, zinc and copper as well as increased demand for gypsum, quartz and other industrial minerals continue to transform large areas of limited habitat types (Milton 2001). Mining has already transformed parts of the landscape, but today many mines have reached the end of their lives and thus pose new challenges for restoration (Milton 2001). A formidable task is to provide locally adapted indigenous propagules on the scale required for restoration. This is a prime opportunity for emerging small-scale businesses.

Livestock grazing has been identified as a major threat to biodiversity in the Succulent Karoo. The dramatic decrease in stocking densities by >50% over the past 100 years (Dean & Macdonald 1994) is thought to reflect this degradation, believed to be most critical in communally grazed areas (Cowling & Hilton-Taylor 1994). Livestock exclusion alone is believed to be insufficient to restore degraded areas (Milton et al. 1994a) that may require

more intensive and expensive interventions. Due to changing economic and political climates, there has been a resurgence of interest in game farming for ecotourism and hunting throughout the Karoo. Although heralded as a sustainable alternative to livestock farming, there are nevertheless real threats, such as the introduction of nonnative herbivores that may modify functional relationships among indigenous herbivores, causing resource competition and niche displacement, genetic pollution and even acting as disease vectors (Castley et al. 2001). Of major and immediate concern is the recent boom in the ostrich farming industry. Historically, ostrich would have moved nomadically between rainfall patches, following watercourses and selecting high-quality forage as they moved (Dean & Milton 1999a). For farming purposes, they are now confined to grazing camps at high densities and have a devastating impact on the vegetation (Milton et al. 1994b). Dryland farming is also on the increase, and is often associated with alluvial dry river courses where pumped water is readily available. Rivers are key habitats for many species and are considered of prime importance in conservation planning as they provide migration corridors for a variety of flora and fauna.

Finally, there is a growing threat from unscrupulous collectors of novelty fauna and flora as well as the threat of large-scale, uncontrolled harvesting of flora with medicinal value. Since many species have restricted distributions, illegal removal of populations from the wild can have devastating effects. Although collectors are required to have permits to remove individuals from the wild, cash-strapped authorities battle to enforce policy and legislation. A potential solution is to remove the pressure on wild populations by encouraging propagation by small-scale local nurseries.

7. Action

An overall framework to guide conservation action in the Succulent Karoo has recently been completed by a team of regional experts funded by Conservation International. The Succulent Karoo Ecosystem Plan (SKEP; Driver & Maze 2002) has now moved into implementation phase, and the expected flurry of conservation-related projects places the biome in an overall extremely positive position. The Critical Ecosystem Partnership Fund (CEPF)—a joint initiative of Conservation International, the Global Environment Facility, the Government of Japan, the John D. and Catherine T. MacArthur Foundation and the World Bank—is seen as an opportunity to use innovative mechanisms to catalyse key activities in under-funded geographic priority areas identified by SKEP, the idea being to target biodiversity conservation by involving specific land users such as agriculture, mining and communal authorities. Key areas identified for action by CEPF in the Succulent Karoo include the expansion of protected area corridors; promotion of best practices in key industrial sectors such as the ostrich and mining industries; retention and restoration of critical biodiversity in areas of greatest land use pressure; integration of conservation priorities into land use planning and policy making; increase of awareness of the Succulent Karoo hotspot and finally the creation of capacity to represent biodiversity and conservation concerns into the future (Driver et al. 2003).

8. Further Research

The Terrestrial Ecosystems Programme on the Karoo Biome funded by the Foundation for Research Development (now NRF) provided a major historical boost to Succulent Karoo research (see Cowling 1986, Cowling & Roux 1987) and the focal study site (Tierberg) attracted significant depth of research attention. Much of this early research is highlighted in Dean & Milton (1999b). CapeNature and SANParks have also stimulated nodes of research and it is hoped that SAEON (South African Environmental Observation Network), initiated in 2002 (see Henschel et al. 2003), will provide a similar impetus. Connections with research initiatives such as the BIOTA Southern Africa Programme (Biodiversity Monitoring Transect Analysis in Southern Africa), with its north-south gradient of observatories have been made and provide promise for understanding biodiversity patterns across land use, landscape and climate gradients within the biome. Clearly there is a need for an understanding of what drives and maintains biodiversity at all scales in the Succulent Karoo Biome, and conservation planning and implementation initiatives such as SKEP (Driver & Maze 2002) have highlighted crucial gaps in our knowledge base (such as poor ecological knowledge of the Hantam-Tanqua-Roggeveld region). There is a very firm place for natural history research to add to our understanding of the interactions between plants, their herbivores, pollinators and dispersal agents, knowledge that is currently far from complete. Species-level information on interactions, coupled with well-dated molecular phylogenies could place us in a better position to understand past evolutionary changes and to predict what may happen under future global change scenarios. This type of information would provide the important background and motivation for conservation actions, but it is currently challenging to obtain financial support for work that is seen to lack immediate management application. Conversely, however, scientifically defensible research, resulting in clear guidelines for management should no longer be seen as add on, simply to justify pure research. The interface between academics and managers has to be strengthened, and books such as Milton & Dean (1996), Dean & Milton (1999b) and more recently Esler et al. (2005) provide practical and scientifically defensible guidelines for sound ecological management of this area. Our research focus should be placed not only on remaining natural areas, but also on the matrix of land uses between protected areas, as these contain a large portion of the biodiversity and may be essential in times of change (e.g. as corridors; allow range shifts to occur). We are in a very fortunate position to be able to produce a vegetation map of the entire biome, an indication that our floristic knowledge is reasonably good, despite some gaps.

9. Descriptions of Vegetation Units

Succulent Karoo Biome encompasses 63 vegetation units, forming six bioregions. Four of these represent traditional regions of Namaqualand (Richtersveld, Namaqualand Hardeveld, Namaqualand Sandveld and Knersvlakte), while the other two regions represent a series of units occupying rainshadow, low-altitude valleys and plains (Rainshadow Valley Karoo) and high-altitude semidesert plains, still characterised by a prevalent winter-rainfall regime (Trans-Escarpment Succulent Karoo). Two of the bioregions (Namaqualand Sandveld and Knersvlakte) are typical lowland units, with overwhelming parts of their respective areas found below 300 m above sea level and show a rather limited altitude span (Figure 5.9). The other bioregions occur at altitudes and span either 200–1 100 m (Richtersveld, Namaqualand Hardeveld and Rainshadow Valley Karoo) or reach as high as 1 550 m (Trans-Escarpment Succulent Karoo). More detail on ecology of these bioregions are found in the Chapter on biomes and bioregions in this book.

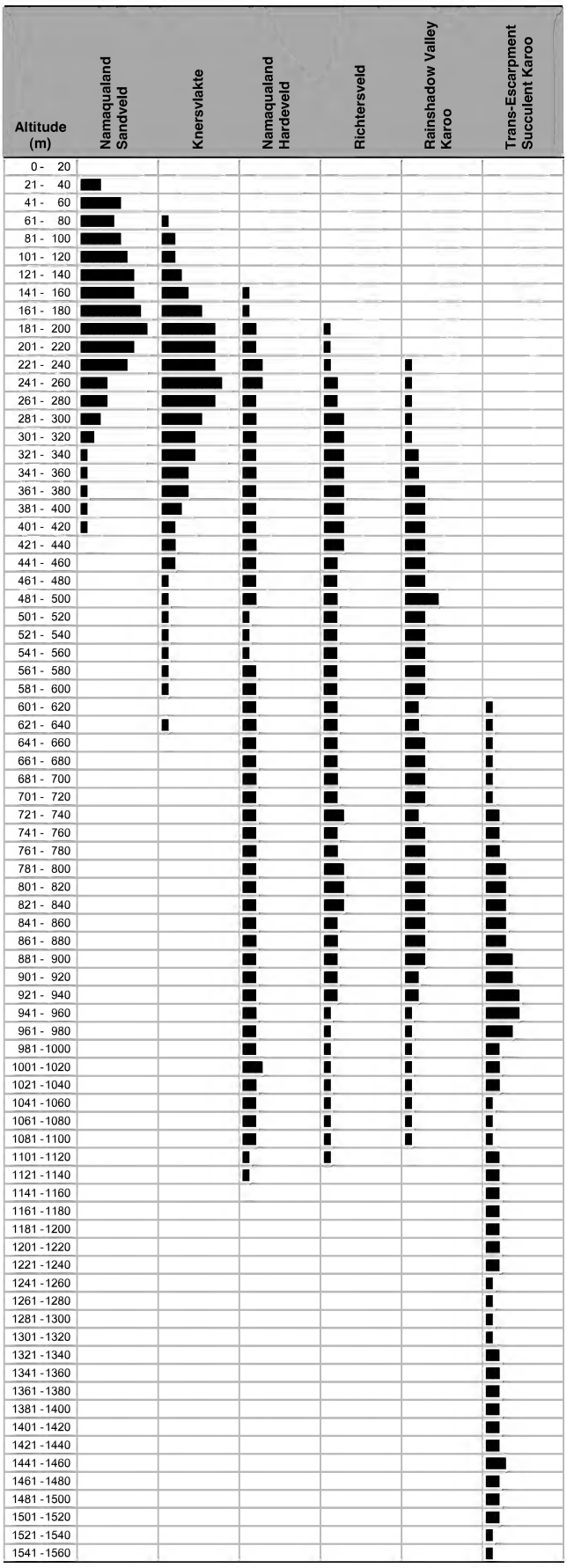


Figure 5.9 Altitudinal profiles of the bioregions of the Succulent Karoo Biome using 20 m classes derived from a digital elevation model (Schulze 1997). The smallest bar represents 1% of the area of the vegetation unit.

Richtersveld

SKr 1 Central Richtersveld Mountain Shrubland

VT 33 Namaqualand Broken Veld (68%) (Acocks 1953). LR 56 Upland Succulent Karoo (100%) (Low & Rebelo 1996).

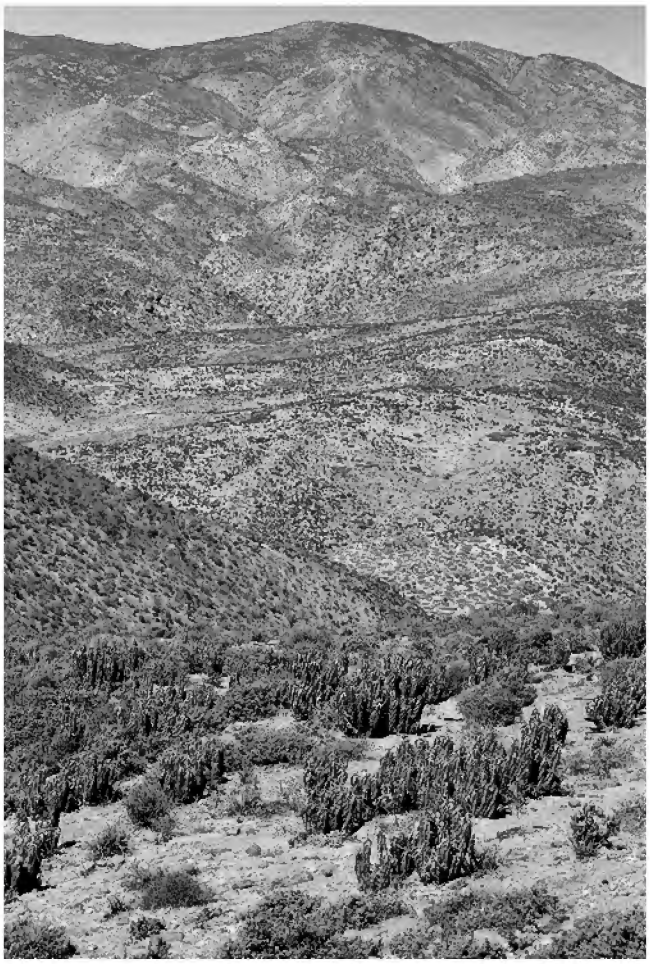
Distribution Northern Cape Province: Central regions of the Richtersveld, along the central mountain ridge from Khodas Peak in the north along the Vandersterrberg and Stinkfontein range stretching about 100 km in a north-south direction, but excluding the highest altitudes where it grades into FFq 1 Stinkfonteinberge Quartzite Fynbos. Altitude 240–1 180 m (most of the area 420–900 m).

Vegetation & Landscape Features Forms the major part of the Richtersveld mountain ranges, including a wide variety of landscapes. Steep and rocky mountains are dominant, with a rolling topography in other parts. Deep canyons, but also wider valleys can be found scattered over most of the area. There is a gradient of increasing density and height of vegetation with increasing altitude and far denser vegetation occurs on the southwestern slopes than on the northeastern slopes (see climate below). The most important types of shrubland are: (a) the sparse dwarf-scrub vegetation of the plains and valley bottoms, with communities dominated by either *Brownanthus pseudoschlichtianus* on loamy or silty soils or *Zygophyllum prismatocarpum* and *Mesembryanthemum pellitum* on calcretes, (b) the chamaephytic to nanophanerophytic shrublands of the low-lying or more arid parts of the mountains, showing high abundance of *Ceraria fruticulosa* and *Euphorbia chersina*, (c) tall (sometimes more than 2 m), dense shrubland at higher altitudes on the mountains with communities similar to the SKn 1 Namaqualand Klipkoppe Shrubland—these communities form a transition towards the high-altitude dry and species-poor forms of quartzite fynbos.

Geology & Soils A spectrum of metavolcanics and metasediments, mostly quartzite, of the Stinkfontein Subgroup of the Gariep Supergroup (Namibian Erathem). Granites of the Mokolian Vioolsdrif Suite are also present. The soils encompass a wide variety of loamy sands, sands and loams. Soils derived from granites may reach a pH between 7 and 8. Land type mainly Ic.

Climate Region of mild, winter-rainfall climate. MAP varies from 60–200 mm, but with most of the area less than 90 mm. At higher altitudes, especially on southwestern slopes, the frequent occurrence of fog or cloud results in a significant improvement in water supply for plants. Frost is very rare at lower altitudes, but occurs up to 10 days per year at higher altitudes.

Important Taxa ([A]At higher altitudes) Succulent Shrubs: *Didelta carnosa* var. *carnosa* (d), *Euphorbia gummifera* (d), *E. mauritanica* (d), *Othonna furcata*[A] (d), *Psilocaulon subnodosum* (d), *Cheiridopsis robusta*, *Cotyledon orbiculata* var. *orbiculata*, *Didelta spinosa*[A], *Euphorbia chersina*, *E. decussata*, *E. ephedroides* var. *ephedroides*, *E. hamata*, *Pelargonium desertorum*, *Senecio sarcoides*, *Tylecodon paniculatus*, *T. viridiflorus*, *Zygophyllum foetidum*[A]. Tall Shrub: *Montinia caryophyllacea*[A]. Low Shrubs: *Berkheya fruticosa*, *Senecio maydae*, *Tripteris oppositifolia*, *T. sinuata*. Herbs: *Tripteris microcarpa* (d), *Colpias mollis*, *Heliophila variabilis*, *Oncosiphon suffruticosum*. Geophytic Herb: *Trachyandra muricata*. Succulent Herbs: *Mesembryanthemum guerichianum* (d), *Trianthema triquetra* (d), *Stapelia hirsuta*.



L. Mucina

Figure 5.10 SKr 1 Central Richtersveld Mountain Shrubland: View of a Richtersveld succulent shrubland with *Aloe pearsonii* (Asphodelaceae) in the foreground (near Die Koei, Richtersveld, Northern Cape)

Biogeographically Important Taxa ([NQ]Namaqualand endemic, [G]Gariep endemic, [R]Richtersveld endemic) Succulent Tree: *Pachypodium namaquanum*[G]. Succulent Shrubs: *Aloe dichotoma* var. *ramosissima*[G] (d), *Ruschia senaria*[R] (d), *Stoeberia frutescens*[NQ] (d), *Zygophyllum prismatocarpum*[NQ] (d), *Cephalophyllum goodii*[R], *Ceraria fruticulosa*[G], *Euphorbia dregeana*[G], *Othonna opima*[R], *Phyllobolus deciduus*[G], *P. decurvatus*[NQ], *Prenia sladeniana*[R], *Tylecodon buchholzianus* subsp. *buchholzianus*[R], *T. ellaphieae*[R], *T. kritzingeri*[R]. Low Shrub: *Galenia dregeana*[R]. Herbs: *Gorteria corymbosa*[G] (d), *Amellus nanus*[G], *Crotalaria pearsonii*[G]. Succulent Herbs: *Brownanthus pseudoschlichtianus*[G] (d), *Mesembryanthemum pellitum*[G] (d), *Crassula grisea*[G].

Endemic Taxa Succulent Shrubs: *Aloe pearsonii* (d), *Astridia speciosa*, *Cheiridopsis pilosula*, *Othonna herrei*. Geophytic Herbs: *Androcymbium exiguum*, *Pseudogaltonia clavata*, *Trachyandra aridimontana*.

Conservation Least threatened. Target 28%. Some 32% statutorily conserved in the Richtersveld National Park. Virtually untransformed, but is subject to strong grazing pressure, mainly by goats. This vegetation unit is of high biodiversity importance due to high species endemism.

Remarks A similar unit occurs in a restricted area on the northern side of the Orange River in Namibia. Although the unit is characterised by high beta diversity along steep altitudinal gradients, it has a surprisingly wide distribution of communities along the north-south gradient. Endemic taxa shared with some neighbouring vegetation units include *Cephalophyllum goodii*, *Galenia dregeana Pelargonium desertorum*, *Senecio maydae* and *Tylecodon kritzingeri*. Some endemic taxa may also occur in equivalent vegetation types in Namibia.

References Van Jaarsveld (1981), Jürgens (1991, 2001, 2004), Jürgens et al. (1997), Boenigk (1998), Osterloh (2000), Van Wyk & Smith (2001), Gotzmann (2002), Schüttler (2002).

SKr 2 Upper Annisvlakte Succulent Shrubland

VT 31 Succulent Karoo (95%) (Acocks 1953). LR 57 Lowland Succulent Karoo (92%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Southern parts of the Annisvlakte north and northwest of the Goariep Mountain in the northwestern Richtersveld from near Khubus to the region southeast of Arrisdrif. The westernmost section, southeast of Arrisdrif, is virtually separated from the main area by a northwards moving duneveld of red sand (part of the SKs 5 Richtersveld Red Duneveld), which at its northern margin fades out to form a shallow sand sheet, which crosses the main road between Alexander Bay and Khubus and penetrating deeply (not mapped) into the Western Gariep Lowlands Desert. Altitude ranges from 150–500 m.

Vegetation & Landscape Features Landscape is mainly a very wide tilted plain, formed by the huge pediment of the Goariep Mountain towards the Orange River. Some river courses are deeply incised into this plain. On the plains, habitats are controlled by soil salinity and texture and by different states of degradation by overgrazing. The present state is interpreted as a result of strong grazing pressure over the past 100 years. At present,

K. Phillips

Figure 5.11 SKr 2 Upper Annisvlakte Succulent Shrubland: Mass germination of *Mesembryanthemum hypertrophicum* (Aizoaceae) on the Annisvlakte near Khubus in the Richtersveld.

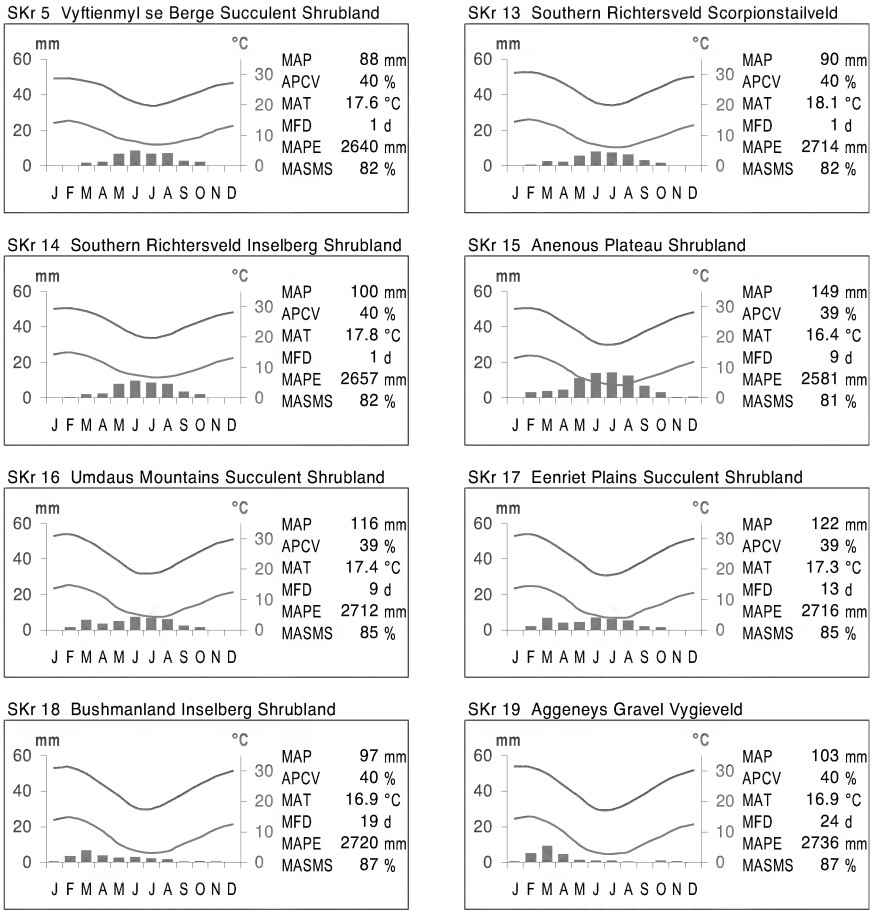


Figure 5.12 Climate diagrams of selected Richtersveld Bioregion units. Blue bars show the median monthly precipitation. The upper and lower red lines show the mean daily maximum and minimum temperature respectively. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days (days when screen temperature was below 0°C); MAPE: Mean Annual Potential Evaporation; MASMS: Mean Annual Soil Moisture Stress (% of days when evaporative demand was more than double the soil moisture supply).

very sparse, dwarf vegetation cover is observed, dominated by annuals, geophytes and, only to a lesser extent, by small leaf-succulent chamaephytes. In the past this unit was probably covered by SKr 7 Northern Richtersveld Scorpionstailveld and partly by the Ruschietum senariae (Jürgens 2001, 2004).

Geology & Soils The granite of the Kuboos Pluton (of the Cambrian Kuboos, Bremen Suite), largely covered by alluvium and superficial calcrete deposits. Alluvial loamy sandy gravel soils, mainly derived from granite. Ae and Ag land types are almost equally important.

Climate MAP is 55–70 mm. Winter rainfall is predominant. Light frost is a very rare event. This region receives sea fog from a southwesterly direction as well as 'malmokkie' fog (see the chapter on Desert in this book). Strong winds to very strong storms occur and cause severe dust and sand storms with consequentially strong erosion of topsoil material and sandblasting.

Important Taxa Succulent Shrubs: *Drosanthemum hispidum* (d), *Euphorbia gummifera* (d), *Psilocaulon subnodosum* (d), *Aridaria noctiflora* subsp. *noctiflora*, *Augea capensis*, *Cheiridopsis robusta*, *Didelta carnosa* var. *carnosa*, *Drosanthemum inornatum*, *Euphorbia ephedroides* var. *ephedroides*, *Hypertelis salsoloides*, *Othonna cylindrica*, *Psilocaulon salicornioides*, *Salsola zeyheri*, *Sarcocaulon crassicaule*. Tall Shrub: *Gomphocarpus fruticosus*. Low Shrubs: *Galenia crystallina* (d), *G. fruticosa* (d), *Asparagus capensis* var. *capensis*, *A. undulatus*, *Hermannia trifurca*, *Lebeckia multiflora*, *Solanum namaquense*. Herbs: *Capnophyllum africanum*, *Gorteria diffusa* subsp. *diffusa*, *Hebenstretia parviflora*, *Heliophila seselifolia* var. *nigellifolia*, *Limeum fenestratum*, *Manulea gariepina*, *Oncosiphon grandiflorum*, *O. piluliferum*, *O. suffruticosum*, *Phyllopodium phyllopodioides*, *Senecio arenarius*, *Tripteris microcarpa*, *Wahlenbergia paniculata*, *Zygophyllum retrofractum*. Geophytic Herbs: *Dipcadi crispum*, *Ferraria divaricata*, *Gethyllis grandiflora*, *Lachenalia undulata*, *Ornithoglossum viride*. Succulent Herbs: *Mesembryanthemum barklyi* (d), *M. guerichianum* (d), *Brownanthus pubescens*, *Psilocaulon dinteri*,*Tetragonia echinata*, *Trianthema triquetra*. Graminoids: *Centropodia glauca*, *Ehrharta calycina*, *Schismus barbatus*, *Stipagrostis ciliata*, *S. obtusa*.

Biogeographically Important Taxa ([NQ]Namaqualand endemic, [G]Gariep endemic) Succulent Shrubs: *Dracophilus dealbatus*[G], *Eberlanzia cyathiformis*[G], *E. ebracteata*[G], *Zygophyllum prismatocarpum*[NQ]. Low Shrub: *Hermbstaedtia glauca*[G]. Herb: *Amellus nanus*[G]. Geophytic Herbs: *Trachyandra bulbinifolia*[NQ], *T. involucrata*[NQ]. Succulent Herbs: *Mesembryanthemum hypertrophicum*[G] (d), *M. barklyi*[NQ], *M. pellitum*[G], *Phyllobolus oculatus*[NQ].

Conservation Least threatened. Target 28%. None conserved in statutory conservation areas. Very little of the area transformed. Comparison of recent with historical photographs shows that soil and vegetation has been severely altered since the early 20th century. The main change is degradation from loamy-sandy topsoils to coarser and more saline soils and the replacement of vegetation once dominated by *Brownanthus pseudoschlichtianus* and *Ruschia senaria* to the present dominance of therophytes and geophytes. At present, the degraded and sparse vegetation permits strong and frequent dust and sand storms. These cause further damage due to degradation of seed banks. The export of topsoil material negatively affects neighbouring areas, e.g. the Cornellskop with its population of *Aloe pillansii*. It is emphasised that this unit needs conservation, mainly through reduction of small stock grazing and perhaps rehabilitation measures in some parts.

References Van Jaarsveld (1981), Jürgens (1991, 2004), Jürgens et al. (1997), Van Wyk & Smith (2001), Oguz et al. (2004).

SKr 3 Goariep Mountain Succulent Shrubland

VT 33 Namaqualand Broken Veld (78%) (Acocks 1953). LR 56 Upland Succulent Karoo (51%) (Low & Rebelo 1996).

Distribution Northern Cape Province: The unit is entirely formed by the Goariep Mountain (Ploegberg)—a large granite inselberg located southwest of the village of Khubus and west of the Vandersterrberg-Stinkfonteinberge mountain range in

the northwestern Richtersveld. Altitude ranges from 300–1 214 m.

Vegetation & Landscape Features The circular geomorphological structure of the Goariep Mountain rises steeply above the surrounding landscape, mostly plains, and culminates in numerous granite domes. The vegetation consists of dense to very dense, tall shrubland with a high frequency of populations of *Aloe dichotoma* var. *ramosissima* and many other shrubs and trees typical of granite rocks and soils. Habitat types differ with regard to texture, nutrient status, aspect and soil moisture levels—the latter being relatively high for a region in close proximity (< 20 km) to the hyper-arid Namib Desert habitats. In the region, the Goariep Mountain Succulent Shrubland has the largest surface area with highest densities of photosynthetically active biomass, as measured by the NDVI index of NOAA or MODIS satellite data in the region.

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Figure 5.13 SKr 3 Goariep Mountain Succulent Shrubland: Dense vegetation on west-facing slopes of the Goariep Mountain. *Stoeberia utilis, S. beetzii, Justicia cuneata* subsp. *latifolia, Tylecodon paniculatus, Jamesbrittenia ramosissima, Sarcostemma viminale, Ceraria fruticulosa* and *Ruschia senaria* are the most important shrubs filling the space between the granite boulders.

Geology & Soils Built of granite of the Kuboos Pluton (Cambrian). Soils are mostly loamy sands. Ic is almost the exclusive land type.

Climate Winter-rainfall area with MAP about 70 mm, increasing with altitude and controlled by geomorphology, probably reaching as high as 200 mm at higher altitudes. High moisture levels are generated by orogenic uplift of moist air by the slopes of the large granite massif of the Goariep Mountain—the first high mountain in the pathway of the air stream moving in from the ocean from southern, southwestern or western directions. Consequently, rainfall and fog generate high precipitation along the southern and western slopes of the mountain, especially at higher altitudes. Frequency of frost depends on the altitude, reaching up to about 10 days per year in the summit area.

Important Taxa Succulent Shrubs: *Cheiridopsis robusta*, *Cotyledon orbiculata* var. *orbiculata*, *Didelta carnosa* var. *carnosa*, *D. spinosa*, *Drosanthemum floribundum*, *D. inornatum*, *Euphorbia chersina*, *E. ephedroides* var. *ephedroides*, *Hypertelis salsoloides*, *Lampranthus otzenianus*, *Othonna cylindrica*, *Stoeberia beetzii, Tetragonia fruticosa*, *Tylecodon paniculatus*, *Zygophyllum cordifolium*. Tall Shrubs: *Montinia caryophyllacea*, *Rhus populifolia*. Low Shrubs: *Asparagus capensis* var. *capensis*, *Berkheya spinosissima* subsp. *namaensis*, *Blepharis furcata*, *Carissa bispinosa* subsp. *bispinosa*, *Dyerophytum africanum*, *Galenia crystallina*, *Helichrysum obtusum*, *Indigofera pungens*, *Jamesbrittenia ramosissima*, *Lebeckia multiflora*, *Pteronia divaricata*, *Salvia garipensis*, *Zygophyllum retrofractum*. Woody Succulent Climbers: *Dioscorea elephantipes*, *Sarcostemma viminale*. Herbs: *Arctotis fastuosa* (d), *Codon royenii*, *Colpias mollis*, *Forsskaolea candida*, *Gorteria diffusa* subsp. *diffusa*, *Grielum humifusum*, *Heliophila seselifolia* var. *nigellifolia*, *H. variabilis*, *Manulea androsacea*, *Oncosiphon piluliferum*, *O. suffruticosum*, *Tripteris microcarpa*. Geophytic Herbs: *Boophone haemanthoides*, *Haemanthus coccineus*. Succulent Herbs: *Mesembryanthemum guerichianum*, *Psilocaulon dinteri*, *P. subnodosum*, *Trianthema triquetra*.

Biogeographically Important Taxa ([NQ]Namaqualand endemic, [G]Gariep endemic, [R]Richtersveld endemic) Succulent Shrubs: *Aloe dichotoma* var. *ramosissima*[G] (d), *Ceraria fruticulosa*[G], *Eberlanzia cyathiformis*[G], *Euphorbia dregeana*[G], *Ruschia senaria*[R], *Stoeberia frutescens*[NQ], *Zygophyllum prismatocarpum*[NQ]. Low Shrubs: *Hermbstaedtia glauca*[G], *Pelargonium tenuicaule*[R]. Geophytic Herbs: *Cyrtanthus herrei*[R], *Trachyandra bulbinifolia*[NQ]. Succulent Herbs: *Brownanthus pseudoschlichtianus*[G], *Crassula grisea*[G], *Mesembryanthemum hypertrophicum*[G].

Conservation Least threatened. Target 28%. None conserved in statutory conservation areas. Due to the close vicinity to the permanent settlement of Khubus and due to the rich resource of exploitable biomass, a long history of strong grazing pressure has degraded the vegetation extensively, especially on the lower slopes of the mountain. Therefore, protection of parts of the higher altitudes, especially in the southwestern region, is recommended.

Remark The name Ploegberg refers to the fact that during the early 20th century ploughed fields were used for the production of cereals in the high-altitude parts of the Goariep Mountain. Its granite flora shows several affinities to that of the Tatasberg (also granite of the same age), for instance by the occurrence of *Jamesbrittenia ramosissima, Berkheya spinosissima* and *Crassula grisea*.

References Van Jaarsveld (1981), Jürgens (1991, 2004), Jürgens et al. (1997), Van Wyk & Smith (2001).

SKr 4 Lekkersing Succulent Shrubland

VT 31 Succulent Karoo (80%) (Acocks 1953). LR 57 Lowland Succulent Karoo (80%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Longitudinal band in the southwestern Richtersveld extending north and south of Lekkersing, with an additional extension to the southeast and some scattered patches further north. All these parts are located in the lowlands west and southwest of the central mountain ridge of the Richtersveld. The core area has a north-south extension of some 70 km from near the Goariep Mountain in

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Figure 5.14 SKr 4 Lekkersing Succulent Shrubland: Sharp ridges of dolomite peaks south of the Goariep Mountain, housing a rich assemblage of species of *Zygophyllum* (including *Z. prismatocarpum*) and a diverse yellow daisy flora (*Osteospermum, Foveolina* and *Pentzia*).

the north to the vicinity of Oograbies in the south. Altitude ranges from about 150–550 m.

Vegetation & Landscape Features Mosaic of hills, flat or slightly rolling plains, with embedded quartz fields and ridges, some sand sheets and dunes, rocky gorges and including some rocky mountains. Quartz and quartzitic rocks are the most important. A wide spectrum of habitat types occurs, ranging from rocky outcrops to dunes. However, most of the area is hilly with shallow loam or sand cover with gravel above bedrock. These areas are covered by leaf-succulent dwarf shrublands, similar to those at low altitudes of the central mountains of the Richtersveld, but showing lower densities. Coastal elements such as *Stoeberia beetzii* can be dominant while *Zygophyllum prismatocarpum* becomes more important in the disturbed areas. *Enarganthe octonaria* has the highest cover on quartzitic rock and *Brownanthus arenosus* or *Cladoraphis spinosus* on the dunes.

Geology & Soils Mainly quartzite, sometimes schist, dolomite of the Precambrian Gariep Complex supporting sandy, skeletal soils. Half of the area is classified as Ag land type, followed by Fc, Ae, Ic.

Climate MAP is 60–120 mm. Winter rainfall is clearly predominant. Coastal fog is not as frequent as along the coast, but more important than in the Richtersveld mountains. Frost is very rare.

Important Taxa Small Tree: *Rhus undulata*. Succulent Shrubs: *Cephalophyllum regale* (d), *C. rigidum* (d), *Adromischus alstonii*, *Aridaria noctiflora* subsp. *noctiflora*, *Cheiridopsis robusta*, *Drosanthemum inornatum*, *Euphorbia chersina*, *E. decussata*, *E. ephedroides* var. *ephedroides*, *E. tuberculata* var. *tuberculata*, *Hypertelis salsoloides*, *Kleinia longiflora*, *Lampranthus otzenianus*, *Octopoma connatum*, *Othonna arbuscula*, *O. cylindrica*, *O. protecta*, *O. sedifolia*, *Pelargonium crithmifolium*, *P. echinatum*, *Ruschia leucosperma*, *Salsola zeyheri*, *Sarcocaulon crassicaule*, *Senecio aloides*, *Tetragonia verrucosa*, *Tylecodon reticulatus*, *Zygophyllum cordifolium*. Low Shrubs: *Zygophyllum microphyllum* (d), *Asparagus capensis* var. *capensis*, *Galenia crystallina*, *G. fruticosa*, *Helichrysum hebelepis*, *H. obtusum*, *Hermannia paucifolia*, *Hirpicium alienatum*, *Pteronia ciliata*, *P. glabrata*, *Tripteris oppositifolia*, *Z. retrofractum*. Herbaceous Climber: *Cysticapnos vesicaria*. Herbs: *Aizoon canariense*, *Atriplex semibaccata* var. *appendiculata*, *Gorteria diffusa* subsp. *diffusa*, *Grielum humifusum*, *Limeum fenestratum*, *Lotononis falcata*, *Lyperia tristis*, *Manulea adrosacea*, *Oncosiphon piluliferum*, *Tripteris hyoseroides*, *T. microcarpa*, *Ursinia cakilefolia*. Geophytic Herbs: *Babiana tritonioides*, *Bulbine sedifolia, Cheilanthes hastata*. Succulent Herbs: *Avonia albissima*, *Conophytum gratum*, *C. hians*, *Crassula columnaris* subsp. *prolifera*, *C. corallina* subsp. *corallina*, *C. deceptor*, *C. hemisphaerica*, *C. muscosa*, *Lithops meyeri*, *Mesembryanthemum guerichianum*, *Phyllobolus nitidus*, *Psilocaulon dinteri*. Graminoids: *Aristida adscensionis*, *Cladoraphis spinosa*, *Stipagrostis obtusa*.

Biogeographically Important Taxa ([NQ]Namaqualand endemic, [G]Gariep endemic, [R]Richtersveld endemic) Succulent Shrubs: *Aspazoma amplectens*[NQ] (d), *Cheiridopsis pillansii*[G], *Eberlanzia ebracteata*[G], *E. sedoides*[G], *Enarganthe octonaria*[R], *Meyerophytum meyeri*[NQ], *Othonna opima*[R], *Phyllobolus deciduus*[G], *P. decurvatus*[NQ], *Schlechteranthus maximilianii*[R], *Stoeberia frutescens*[NQ], *Tylecodon racemosus*[NQ], *Zygophyllum prismatocarpum*[NQ]. Herbs: *Adenoglossa decurrens*[NQ], *Crotalaria pearsonii*[G]. Geophytic Herbs: *Cyrtanthus herrei*[R], *Trachyandra bulbinifolia*[NQ]. Succulent Herbs: *Brownanthus pseudoschlichtianus*[G], *Mesembryanthemum pellitum*[G], *Phyllobolus oculatus*[NQ], *Stapeliopsis neronis*[R].

Endemic Taxa Succulent Shrubs: *Cheiridopsis purpurea*, *Nelia schlechteri*, *Tylecodon longipes*, *T. torulosus*.

Conservation Least threatened. Target 28%. None conserved in statutory conservation areas. In places vegetation is highly degraded by overgrazing, especially in a radius of approximately 6 km around Lekkersing. Protection of a substantial area of the quartz fields near Vlakmyn and of the quartzitic rocks south of Lekkersing, including the Karachabpoort, is recommended.

Remark 1 The placement of small granite inselbergs such as Grootberg and Springklipberg (in the northernmost patches) is problematic. They are included in Lekkersing Succulent Shrubland, based on the occurrence of more arid floristic elements. They are, however, geologically closer to the Goariep Mountain.

Remark 2 Certain quartzitic gorges like the Karachabpoort (south of Lekkersing) are very rich in species, including *Cyrtanthus herrei, Cheilanthes hastata, Helichrysum hebelepis, Rhus undulata, Cysticapnos vesicaria, Pelargonium echinatum* and *Crotalaria pearsonii* as well as endemics such as *Tylecodon torulosus* and *T. longipes*. Quartz fields, e.g. at Herre's famous Vlakmyn area, house endemic or locally rare species like *Nelia pillansii* and *Lithops meyeri*.

References Van Jaarsveld (1981), Jürgens (1991, 2004), Jürgens et al. (1997), Van Wyk & Smith (2001).

SKr 5 Vyftienmyl se Berge Succulent Shrubland

VT 31 Succulent Karoo (100%) (Acocks 1953). LR 57 Lowland Succulent Karoo (100%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Southwestern Richtersveld—a north-south trending longitudinal series of inselbergs (making up the Vyftienmyl se Berge) some 20 km inland east of Port Nolloth. Altitude ranges from 200–485 m.

Vegetation & Landscape Features Steep, wall-like, linear series of inselbergs—a prominent geomorphological structure when viewed from the coastal plains near Port Nolloth. The habitat conditions are governed by altitude, rockiness and aspect. Impact of winds and of fog precipitation on the western slopes and much drier conditions on the eastern slopes are reflected in a wide range of vegetation types. High shrublands can be found in sheltered places which receive runoff water from higher rock areas, while exposed rocks support vegetation with very small succulents (*Conophytum, Tylecodon*) and lichens. Slopes with gravel or loam support the woody leaf succulent chamaephytes (e.g. *Enarganthe octonaria, Ruschia senaria*) typical of the Succulent Karoo.

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Figure 5.15 SKr 5 Vyftienmyl se Berge Succulent Shrubland: Vyftienmyl se Berge form a barrier for the sea fog and moist oceanic air moving inland from the coastline (15–20 km away), and support a fairly dense cover of leaf-succulent shrubs (e.g. *Enarganthe octonaria, Aspazoma amplectens, Ruschia senaria*), while small succulents and lichens are abundant on rock surfaces.

Geology & Soils Mainly quartzite and some other metasediments of the Stinkfontein Subgroup (Gariep Supergroup). Wide range of soil types, mostly weakly developed (Mispah and Glenrosa form, partly Dorbank). The region is classified as Ic land type.

Climate MAP is estimated to range from 60–120 mm. Winter rainfall with strong differences between different slopes. Due to its geomorphological structure and due to the location in the sandveld plains close to the coast, the mountains receive considerable amounts of fog water, especially on the western slopes. Fog frequency is estimated at ca. 60 to 80 days per year. Besides the Boegoe Twins near Alexander Bay, the mountains at Vyftienmyl se Berge are the best example of a 'fog oasis' on the northern Namaqualand coastal plain. Frost is rare. See also climate diagram for SKr 5 Vyftienmyl se Berge Succulent Shrubland (Figure 5.12).

Important Taxa Succulent Shrubs: *Adromischus montium-klinghardtii*, *A. roaneanus*, *Cotyledon orbiculata* var. *orbiculata*, *Euphorbia hamata*, *Mitrophyllum grande*, *Othonna arbuscula*, *Tylecodon buchholzianus*, T. *paniculatus*, *T. reticulatus*, *T. rubrovenosus*, *T. wallichii* subsp. *wallichii*. Low Shrubs: *Blepharis mitrata*, *Euryops dregeanus*, *Justicia cuneata* subsp. *cuneata*, *Pteronia ciliata*, *Senecio maydae*. Herbs: *Gorteria diffusa* subsp. *diffusa*, *Hebenstretia parviflora*, *Lyperia tristis*. Geophytic Herbs: *Gethyllis lanuginosa*, *Gladiolus arcuatus*. Succulent Herbs: *Crassula barklyi*, *C. columella*, *C. columnaris* subsp. *prolifera*, *C. pseudohemisphaerica*, *Gasteria pillansii* var. *ernesti-ruschii*.

Biogeographically Important Taxa ([NQ]Namaqualand endemic, [G]Gariep endemic, [R]Richtersveld endemic) Succulent Shrubs: *Aspazoma amplectens*[NQ] (d), *Ruschia senaria*[R] (d), *Cheiridopsis speciosa*[R], *Enarganthe octonaria*[R], *Hallianthus planus*[NQ], *Meyerophytum meyeri*[NQ], *Mitrophyllum clivorum*[NQ], *Schlechteranthus maximilianii*[R], *Tylecodon racemosus*[NQ], *T. similis*[NQ]. Woody Climber: *Microloma calycinum*[NQ]. Succulent Herbs: *Conophytum obscurum* subsp. *obscurum*[R], *Crassula grisea*[G].

Endemic Taxa ([Q]Quartz substrates) Succulent Shrubs: *Mitrophyllum abbreviatum*[Q], *Tylecodon bodleyi*. Geophytic Herbs: *Bulbine lavrani*, *B. torsiva*, *B. vitrea*. Succulent Herbs: *Anacampseros scopata*, *Conophytum bolusiae* subsp. *bolusiae*[Q], *C. francoiseae*, *C. jucundum* subsp. *marlothii*[Q], *C. stephanii* subsp. *stephanii*.

Conservation Target 28%. None conserved in statutory conservation areas. Threatened by farming actions and by illegal plant collecting from the nearby roads. The unit carries numerous succulent species that have been described as endemics or near-endemics, although some of them have unclear taxonomic status. The unit also forms an extraordinary 'fog oasis' with peculiar dwarf succulent formations. Due to these properties the unit has a high conservation value and should be well protected.

References Van Jaarsveld (1981), Jürgens (1991, 2004), Jürgens et al. (1997), Van Wyk & Smith (2001).

SKr 6 Stinkfonteinberge Eastern Apron Shrubland

VT 28 Western Mountain Karoo (66%) (Acocks 1953). LR 56 Upland Succulent Karoo (100%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Narrow belt immediately east of the Stinkfonteinberge range in the southeastern Richtersveld. It has a north-south-trending longitudinal extension of about 35 km from just south of the Rosyntjieberge to immediately north of Eksteenfontein. Altitude ranges from 500–800 m.

Vegetation & Landscape Features Lower flat slopes and the subsequent pediment at the foot of the Stinkfonteinberge range. Also includes a number of small mountains. Mainly flat

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Figure 5.16 SKr 6 Stinkfonteinberge Eastern Apron Shrubland: Slopes and plains near Jenkinskop east of the Stinkfonteinberge are strongly degraded by over-grazing and erosion. Disturbance indicator species, such as *Manochlamys albicans*, *Hermbstaedtia glauca* and *Oncosiphon suffruticosum*, are dominant.

to rolling landscape at the foot of the higher mountains, characterised by deeper sandy or silty loams similar to soils of the SKr 7 Northern Richtersveld Scorpionstailveld. Distinguished from the latter by more variable topography, much lower vegetation density, and high incidence of indicators of degradation.

Geology & Soils Granites of the Mokolian Vioolsdrif Suite predominate, with Stinkfontein Subgroup Quartzites (Namibian Erathem) along western fringes. Soils are composed of silt or loam with calcretes and show extreme erosion in places. Ag land type is dominant in the region, while Ic is of lesser importance.

Climate Predominantly winter rainfall, with MAP estimated from 50–120 mm. Lies within a gradient of orogenic rains, rapidly decreasing from west to east. Fog is an infrequent phenomenon. Incidence of fog is low.

Important Taxa Succulent Shrubs: *Aridaria noctiflora* subsp. *noctiflora*, *Crassula macowaniana*, *Didelta carnosa* var. *carnosa*, *Euphorbia decussata*, *E. ephedroides* var. *ephedroides*, *E. mauritanica*, *Hypertelis salsoloides*, *Lampranthus otzenianus*, *L. watermeyeri*, *Leipoldtia schultzei*, *Manochlamys albicans*, *Othonna furcata*, *Pelargonium crithmifolium*, *P. echinatum*, *Psilocaulon subnodosum*, *Sarcocaulon salmoniflorum*, *Tetragonia reduplicata*, *T. spicata*, *Tylecodon paniculatus*, *Zygophyllum foetidum*. Low Shrubs: *Atriplex vestita* var. *appendiculata*, *Chrysocoma ciliata*, *Eriocephalus ericoides*, *E. scariosus*, *Galenia africana*, *G. crystallina*, *Hermannia amoena*, *H. cuneifolia*, *H. stricta*, *Lebeckia cinerea*, *Lessertia fruticosa*, *Osteospermum armatum*, *Pteronia ciliata*, *P. glabrata*, *Stachys lamarckii*, *Tripteris sinuata*, *Zygophyllum retrofractum*. Woody Succulent Climber: *Sarcostemma viminale*. Woody Climber: *Asparagus retrofractus*. Semiparasitic Epiphytic Shrub: *Tapinanthus oleifolius*. Herbs: *Arctotis fastuosa* (d), *Amellus microglossus*, *Atriplex semibaccata* var. *appendiculata*, *Dimorphotheca sinuata*, *Felicia minima*, *Forsskaolea candida*, *Foveolina dichotoma*, *Gorteria diffusa* subsp. *diffusa*, *Helichrysum micropoides*, *Heliophila variabilis*, *Lotononis falcata*, *Nemesia anisocarpa*, *Oncosiphon piluliferum*, *O. suffruticosum*, *Plantago cafra*, *Senecio piptocoma*, *S. sisymbriifolius*. Geophytic Herbs: *Albuca maxima*, *Gladiolus saccatus*, *Oxalis pes-caprae*. Succulent Herbs: *Crassula muscosa*, *Mesembryanthemum cryptanthum*, *Psilocaulon dinteri*. Graminoids: *Ehrharta delicatula*, *Fingerhuthia africana*.

Biogeographically Important Taxa ([NQ]Namaqualand endemic, [G]Gariep endemic, [R]Richtersveld endemic) Small Tree: *Ozoroa concolor*[NQ]. Succulent Shrubs: *Ceraria fruticulosa*[G], *Prenia sladeniana*[R], *Ruschia senaria*[R], *Zygophyllum prismatocarpum*[NQ]. Low Shrubs: *Berkheya canescens*[G], *Hermbstaedtia glauca*[G], *Pelargonium tenuicaule*[R]. Herb: *Amellus nanus*[G]. Geophytic Herbs: *Ornithogalum pruinosum*[NQ], *Trachyandra bulbinifolia*[NQ]. Succulent Herbs: *Brownanthus pseudoschlichtianus*[G] (d), *Mesembryanthemum barklyi*[NQ], *M. hypertrophicum*[G], *M. pellitum*[G].

Conservation Least threatened. Target 28%. About 2% statutorily conserved in the Richtersveld National Park. High disturbance and degradation of vegetation and soils are indicated by abundant *Hermbstaedtia glauca, Galenia africana, Fingerhuthia africana* and *Mesembryanthemum cryptanthum*. The unit shows extreme forms of gully erosion and sheet erosion compared to other parts of the Richtersveld. It is postulated that it has been a dense Scorpionstailveld with *Ruschia senaria* populations before, in which over-exploitation triggered extreme erosion of the deep loamy soils. Many fence lines subdivided formerly communal land into 'economic units', resulting in land use change from nomadic pressures to localised over-exploitation. The area urgently needs protection or management, particularly in terms of erosion control.

References Van Jaarsveld (1981), Jürgens (1991, 2004), Jürgens et al. (1997), Van Wyk & Smith (2001).

SKr 7 Northern Richtersveld Scorpionstailveld

VT 31 Succulent Karoo (64%) (Acocks 1953). LR 57 Lowland Succulent Karoo (51%) (Low & Rebelo 1996).

Distribution Northern Cape Province: A series of plains or valley floors scattered in the northern Richtersveld, including the large Goariepvlakte, Koeroegabvlakte, some plains between Abiequarivier and Gannakourieprivier and at the western entrance to the Springbokvlakte. Altitude ranges from 260–760 m.

Vegetation & Landscape Features Typically fragmented, and showing a landscape of flat, though often tilted, or very slightly undulating topography. Often the whole large plain is covered by the unit, while in other cases it is restricted to specific geomorphological forms such as pediments west of the main mountains and to locations along the river beds protected against deflation by strong winds (Numees area). *Brownanthus pseudoschlichtianus* is typically dominant, with some other plants regularly associated (such as the geophyte *Trachyandra muricata*). Most of the SKr 7 Northern Richtersveld Scorpionstailveld is covered by a regular pattern of heuweltjies, which mostly support populations of *Mesembryanthemum hypertrophicum, M. pellitum, M. squamulosum* and *Psilocaulon subnodosum*.

Geology & Soils The small northeastern part of this area is underlain by granites of the Vioolsdrif Suite; the rest occurs on Cenozoic alluvium, aeolian sand and calcrete. Loamy or silty soils formed by aeolian deposition. Calcrete layers or other calcium carbonate accumulations occur not deeper than 40 cm below the surface. Often the soils also show high salinity. The silt component is subject to local aeolian erosion and sedimentation, resulting in erosion in the bare areas between the bushes and silt deposition underneath the bushes—these biogenic mounds regularly attract ants and termites. Almost 70% of the unit is classified as Ae land type, while the Ag and Ah land types are only of marginal importance.

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Figure 5.17 SKr 7 Northern Richtersveld Scorpionstailveld: Loamy-sandy plains south of the Goariep Mountain on the road to Lekkersing with *Brownanthus pseudoschlichtianus* and *Mesembryanthemum barklyi* dominant and species of *Ursinia* (orange) and *Hypertelis salsoloides* (pink) in between.

Climate Due to the wide range of the unit, a wide spectrum of climatic conditions can be found. MAP may vary greatly (50–100 mm) and falls mainly in winter. Fog can be important, but not east of the Vandersterrberge. Temperatures can follow a wide spectrum. However, in the northeastern Richtersveld a well-developed Scorpionstailveld is seldom found in the hotter areas below an altitude of 330 m. Some days of frost per year can occur at higher altitudes, e.g. on the Koeroegabvlakte.

Important Taxa Succulent Shrubs: *Aridaria noctiflora* subsp. *noctiflora*, *A. serotina*, *Cheiridopsis robusta*, *Drosanthemum inornatum*, *Hypertelis salsoloides*, *Lampranthus otzenianus*. *Psilocaulon subnodosum*. Low Shrubs: *Lebeckia multiflora*, *Zygophyllum retrofractum*. Herbs: *Oncosiphon piluliferum*, *Senecio piptocoma*. Geophytic Herb: *Trachyandra muricata*. Succulent Herbs: *Psilocaulon salicornioides*, *Tetragonia echinata*.

Biogeographically Important Taxa ([NQ]Namaqualand endemic, [G]Gariep endemic) Succulent Shrubs: *Eberlanzia ebracteata*[G], *Euphorbia dregeana*[G], *Phyllobolus deciduus*[G], *P. decurvatus*[NQ]. Low Shrub: *Anticharis scoparia*[G]. Geophytic Herb: *Trachyandra bulbinifolia*[NQ]. Succulent Herbs: *Brownanthus pseudoschlichtianus*[G] (d), *Mesembryanthemum barklyi*[NQ], *M. hypertrophicum*[G], *M. pellitum*[G], *Phyllobolus oculatus*[NQ].

Conservation Least threatened. Target 28%. More than 20% statutorily conserved in the Richtersveld National Park. Overgrazing and trampling of the Scorpionstailveld has led to erosion of the silty-sandy to loamy topsoil. Over long periods of time this process has resulted in the replacement of topsoil and vegetation by less productive vegetation dominated by short-lived vygies such as *Mesembryanthemum hypertrophicum, M. squamulosum, M. pellitum* and *Psilocaulon subnodosum,* and by nonsucculent annuals. Even its protection status does not necessarily prevent degradation (as in the Richtersveld National Park). A certain density of small stock farming by the northern Richtersveld community is permitted. At present, the highest density of stock posts within the Richtersveld National Park has been found in the Koeroegabvlakte (H. Hendricks, personal communication), which forms one of the largest patches of the SKr 7 Northern Richtersveld Scorpionstailveld. Conservation management of these vegetation units is strongly recommended.

References Van Jaarsveld (1981), Jürgens (1991, 2004), Jürgens et al. (1997), Boenigk (1998), Oguz (2000), Osterloh (2000), Van Wyk & Smith (2001), Gembler (2002), Gotzmann (2002), Nußbaum (2003), Oguz et al. (2004), Veste et al. (2004).

SKr 8 Rosyntjieberg Succulent Shrubland

VT 28 Western Mountain Karoo (62%) (Acocks 1953). LR 56 Upland Succulent Karoo (100%) (Low & Rebelo 1996).

Distribution Northern Cape Province: High mountain range (including Rosyntjieberg and Mount Terror) at latitude of Khubus in the northeastern Richtersveld, extending at right angles from the central Vandersterrberg-Stinkfonteinberge mountain range eastwards to just short of the Orange River. Altitude ranges from about 550–1 329 m at the mountain summit.

Vegetation & Landscape Features The Rosyntjieberg landscape differs from the Vandersterrberge by the predominance of exposed rock and very steep slopes. Some of the mountains have nearly vertical escarpments with strong rock weathering, thereby limiting access to some parts of the unit. Due to the high aridity and relatively higher temperatures (compared to the more western mountains, which are more often exposed to cooling air from the Atlantic Ocean) and the rockiness, a very harsh spectrum of habitat conditions limits plant growth in most parts of the unit. More favoured habitats, with somewhat better soil development, show sparse dwarf shrubland similar to that of the SKr 1 Central Richtersveld Mountain Shrubland (e.g. *Ruschia senaria, Euphorbia dregeana, Ceraria fruticulosa*), while in other parts of the unit Succulent Karoo species are mixed with Nama-Karoo elements (e.g. *Aloe dichotoma, Ceraria namaquensis, Tylecodon hallii, Wellstedia dinteri*).

Geology & Soils Mainly quartzite of the Rosyntjieberg Formation (Orange River Group), but also granite of the Vioolsdrif Suite (both Mokolian). The shallow soils are mostly of loamy to sandy texture. The exclusive land type is Ic.

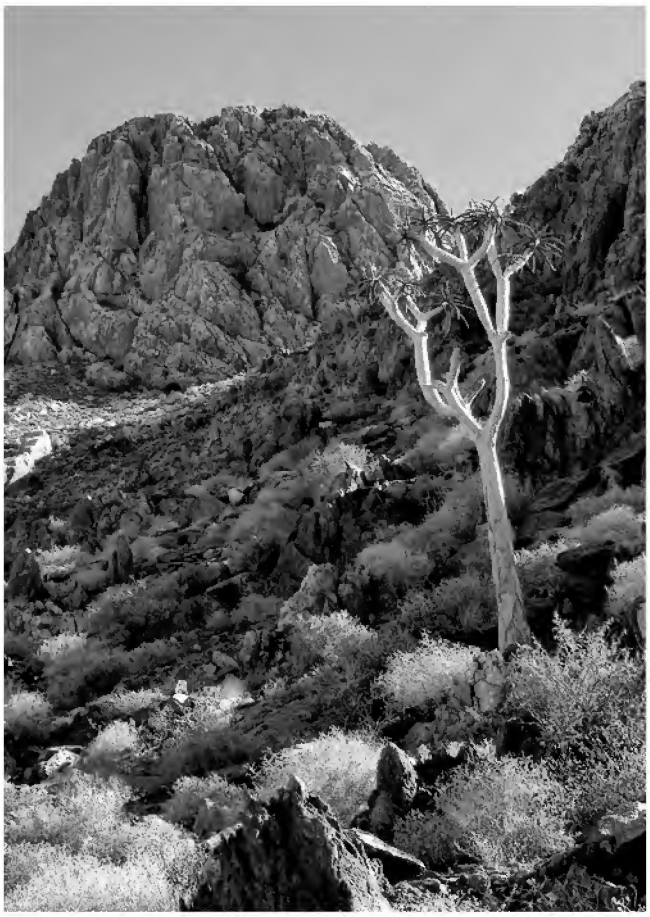

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Figure 5.18 SKr 8 Rosyntjieberg Succulent Shrubland: Succulent shrubland on southern middle slopes of the Rosyntjieberg with *Aloe dichotoma* var. *dichotoma* and shrubs such as *Galenia* and *Lycium*.

Climate Mainly, especially at higher altitude, clear predominance of winter rainfall, while in the lowlands, especially in the more eastern part, rare summer rainfall events may be more important. The region lies in the rainshadow of the Vandersterrberge, with MAP of only 50–90 mm (all these estimates derived from correlations with plant cover). Frequency of frost is estimated at a few to 10 days per year. Fog plays no role.

Important Taxa Succulent Tree: *Aloe dichotoma* var. *dichotoma*. Succulent Shrubs: *Euphorbia chersina* (d), *E. guerichiana*, *Kleinia cephalophora*, *Lycium horridum*, *Pelargonium dasyphyllum*, *P. desertorum*, *Sarcocaulon crassicaule*, *Tylecodon hallii*. Tall Shrubs: *Commiphora capensis*, *Diospyros ramulosa*, *Montinia caryophyllacea*, *Polemanniopsis marlothii*, *Pteronia lucilioides*. Low Shrubs: *Wellstedia dinteri* (d), *Antherothamnus pearsonii*, *Fagonia capensis*, *Heliophila cornuta* var. *squamata*, *Hermannia disermifolia*, *H. minutiflora*, *H. stricta*, *Nolletia gariepina*, *Pharnaceum albens*, *Polygala leptophylla*, *Pteronia divaricata*, *Salvia garipensis*, *Selago beaniana*, *Senecio maydae*, *Zygophyllum microphyllum*. Woody Succulent Climber: *Dioscorea elephantipes*. Herbaceous Climber: *Cyphia crenata*. Herbs: *Acanthopsis disperma*, *Arctotis fastuosa*, *Chascanum garipense*, *Cleome foliosa* var. *lutea*, *Colpias mollis*, *Geigeria vigintisquamea*, *Hebenstretia namaquensis*, *Heliophila cornellsbergia*, *H. deserticola*, *Leysera tenella*, *Lotononis rabenaviana*, *Manulea gariepina*, *Polycarena tenella*, *Wahlenbergia androsacea*, *W. meyeri*. Geophytic Herbs: *Albuca viscosa*, *Melasphaerula ramosa*, *Pterygodium schelpei*. Succulent Herbs: *Crassula umbella*, *Gasteria pillansii* var. *pillansii*, *Lithops geyeri*. Graminoids: *Aristida adscensionis*, *Ehrharta calycina*, *E. delicatula*, *Enneapogon scaber*, *Tribolium utriculosum*.

Biogeographically Important Taxa ([NQ]Namaqualand endemic, [G]Gariep endemic, [R]Richtersveld endemic) Succulent Shrubs: *Euphorbia dregeana*[G] (d), *Ruschia senaria*[R] (d), *Ceraria fruticulosa*[G], *C. namaquensis*[G], *Tylecodon ellaphieae*[R], *T. kritzingeri*[R]. Tall Shrubs: *Calliandra redacta*[G], *Gymnosporia gariepensis*[R]. Low Shrubs: *Monechma mollissimum*[G], *Pelargonium spinosum*[G]. Geophytic Herb: *Whiteheadia bifolia*[NQ].

Endemic Taxa Succulent Shrub: *Aloe meyeri*. Succulent Herbs: *Conophytum taylorianum* subsp. *rosynense, Larryleachia cactiformis* var. *felina*.

Conservation Least threatened. Target 28%. The entire unit is statutorily conserved in the Richtersveld National Park. Untransformed, yet based on a contract with the northern Richtersveld community, there is continued small stock grazing in the Park. A number of local endemics underline the importance of the unit, which has no parallel in nearby Namibia.

Remark An altitudinal coenocline, reflected in transition from Succulent Karoo (dominant at higher altitudes) to vegetation with a stronger admixture of Nama-Karoo elements at lower altitudes can be observed within this vegetation unit.

References Van Jaarsveld (1981), Jürgens (1991, 2004), Jürgens et al. (1997), Van Wyk & Smith (2001).

SKr 9 Tatasberg Mountain Succulent Shrubland

VT 33 Namaqualand Broken Veld (100%) (Acocks 1953). LR 56 Upland Succulent Karoo (100%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Tatasberg—a prominent granitic inselberg massif north of the Springbokvlakte in the northeastern Richtersveld. The southern slope forms an important part of the vegetation unit. Altitude ranges from about 560–1 026 m at the summit.

Vegetation & Landscape Features Huge granitic domes separated by fields of large boulders. The impression is a mosaic of rocky habitats with sparse shrubby vegetation in places. At the base of large granite domes dense low woodland sometimes occurs. On the rocks, mostly restricted to smaller fissures, succulent chamaephytes dominate.

Geology & Soils Acid and intermediate metavolcanics and metasediments of the Orange River Group (Mokolian) as well as granite and syenite of the Tatasberg Complex (Cambrian Kuboos, Bremen Suite). Soils are very shallow and only very patchy. Deeper and more developed soils are formed in cracks and crevices in places that receive larger amounts of rainfall runoff. Ic land type is dominant.

Climate MAP estimated at 50–120 mm and appears to be less in the rainshadow of the Vandersterrberge than on the Rosyntjieberg. Due to the higher altitude, the Tatasberg catches more rainfall and less water evaporates, in strong contrast to the surrounding (mostly desert) areas. Rainfall seasonality has transitional features between winter and summer rainfall, and is poorly predictable. High temperatures in summer are common. Very few frost days per year. Fog does not play an important role.

Important Taxa Succulent Tree: *Aloe dichotoma* var. *dichotoma*. Small Tree: *Ficus ilicina*. Succulent Shrubs: *Euphorbia decussata*, *Pelargonium alternans*, *P. dasyphyllum*, *P. desertorum*, *Phyllobolus gariepensis*, *Zygophyllum dregeanum*. Tall Shrubs: *Commiphora capensis*, *Diospyros ramulosa*, *Montinia caryophyllacea*, *Nymania capensis*, *Pentatrichia petrosa*, *Rhynchosia*

schlechteri. Low Shrubs: *Antherothamnus pearsonii*, *Aptosimum indivisum*, *Berkheya spinosissima* subsp. *namaensis*, *Blepharis furcata*, *Carissa bispinosa* subsp. *bispinosa*, *Dyerophytum africanum*, *Eriocephalus scariosus*, *Galenia pruinosa*, *Hermannia minutiflora*, *Indigofera adenocarpa*, *I. pungens*, *Jamesbrittenia ramosissima*, *J. sessilifolia*, *Lophiocarpus polystachyus*, *Monechma spartioides*, *Nolletia gariepina*, *Pegolettia oxyodonta*, *Petalidium parvifolium*, *Pteronia divaricata*, *Rhynchosia emarginata*, *Salvia garipensis*, *Selago angustibractea*, *Solanum burchellii*, *Stachys rugosa*. Semiparasitic Epiphytic Shrubs: *Septulina glauca*, *Tapinanthus oleifolius*, *Viscum capense*, *V. rotundifolium*. Herbs: *Aizoon canariense*, *Amellus epaleaceus*, *Cucumis rigidus*, *Felicia namaquana*, *Helichrysum gariepinum*, *H. herniarioides*, *Hypertelis spergulacea*, *Indigastrum argyroides*, *Indigofera hololeuca*, *Lyperia tristis*, *Manulea crassifolia*, *M. robusta*, *Mollugo tenella*, *Monsonia luederitziana*, *Myxopappus acutilobus*, *Senecio eenii*, *Tephrosia dregeana* var. *dregeana*, *Tripteris pinnatilobata*, *Troglophyton parvulum*, *Wahlenbergia patula*, *Zaluzianskya diandra*. Geophytic Herbs: *Asplenium cordatum*, *Cheilanthes deltoidea*, *C. rawsonii*, *Lachenalia polypodantha*, *Lapeirousia plicata* subsp. *plicata*. Succulent Herbs: *Trianthema triquetra* (d), *Anacampseros karasmontana*, *Crassula tenuipedicellata*. Graminoids: *Enneapogon scaber*, *Pentaschistis airoides*, *Stipagrostis anomala*, *S. obtusa*.

Biogeographically Important Taxa ([NQ]Namaqualand endemic, [G]Gariep endemic, [R]Richtersveld endemic) Succulent Shrubs: *Ceraria namaquensis*[G] (d), *Eberlanzia ebracteata*[G], *Lycium grandicalyx*[G], *Schwantesia herrei*. Tall Shrub: *Gymnosporia gariepensis*[R]. Low Shrubs: *Anticharis scoparia*[G], *Gaillonia crocyllis*[G], *Galenia dregeana*[R], *Melianthus pectinatus*[NQ], *Monechma mollissimum*[G], *Pelargonium spinosum*[G]. Herb: *Gorteria corymbosa*[G]. Geophytic Herbs: *Ornithogalum geniculatum*[NQ], *Oxalis copiosa*[NQ], *Tritonia marlothii* subsp. *marlothii*[R]. Succulent Herbs: *Brownanthus nucifer*[G], *Crassula grisea*[G], *Mesembryanthemum gariusanum*[G].

Conservation Least threatened. Target 34%. The entire unit is statutorily conserved in the Richtersveld National Park. No transformation observed.

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Figure 5.19 SKr 9 Tatasberg Mountain Succulent Shrubland: Solitary, disintegrating granite dome of the Tatasberg (1 028 m) north of the Springbokvlakte in the Richtersveld National Park, supporting succulent shrubland. Viewed from the foot covered by desert vegetation of the unit Dg 3 Richtersveld Sheet Wash Desert.

Remark The flora of this unit, due to similarities in geology, shows affinities to the Ploegberg (SKr 3 Goariep Mountain Succulent Shrubland).

SKr 10 Die Plate Succulent Shrubland

VT 33 Namaqualand Broken Veld (69%) (Acocks 1953). LR 56 Upland Succulent Karoo (91%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Plateau east of Lekkersing and south of Eksteenfontein in southern Richtersveld. Altitude ranges from 300–800 m.

Vegetation & Landscape Features A plateau with a series of open flat steps descending from north to south with isolated embedded hills. Habitat types show little differences within the flats. The regular pattern of large heuweltjies is a remarkable feature of the region. Vegetation is a dwarf shrubland, probably strongly shaped by intensive grazing and the vegetation shows clear signs of degradation. Consequently, degradation indicators, such as *Drosanthemum floribundum*, *D. inornatum* and *Galenia sarcophylla*, are dominant elements in the vegetation.

Geology & Soils Mainly quartzite rocks of the Stinkfontein Formation of the Precambrian Gariep Complex. Soils are mainly shallow and with loamy-sandy texture. Ag is the almost exclusive land type of this unit.

Climate MAP is estimated at 80–120 mm, with winter-rainfall pattern clearly predominant. Frost is a very rare event and fog is of little importance.

Important Taxa Succulent Shrubs: *Drosanthemum floribundum* (d), *D. inornatum* (d), *Galenia sarcophylla* (d), *Aridaria noctiflora* subsp. *noctiflora*, *Crassula macowaniana*, *Didelta carnosa* var. *carnosa*, *Euphorbia ephedroides* var. *ephedroides*, *Lampranthus otzenianus*, *Manochlamys albicans*, *Ruschia hexamera*, *Senecio aloides*, *Tetragonia verrucosa*, *Tylecodon paniculatus*, *Zygophyllum cordifolium*. Low Shrubs: *Galenia africana*, *G. crystallina*, *Helichrysum asperum* var. *albidulum*, *Pteronia glabrata*, *Tripteris oppositifolia*. Semiparasitic Shrub: *Thesium lineatum*. Herbs: *Atriplex semibaccata* var. *appendiculata*, *Gazania leiopoda*, *Gorteria diffusa* subsp. *diffusa*, *Lessertia diffusa*, *Oncosiphon piluliferum*, *O. suffruticosum*, *Rhynchopsidium pumilum*, *Senecio arenarius*, *Tripteris clandestina*, *T. hyoseroides*, *Ursinia cakilefolia*. Geophytic Herbs: *Albuca cooperi*, *A. maxima*, *Bulbine namaensis*, *B. succulenta*, *Cyanella ramosissima*, *Gladiolus orchidiflorus*, *Lachenalia verticillata*, *Ornithogalum glandulosum*. Succulent Herbs: *Crassula pseudohemisphaerica*, *Haworthia arachnoidea*, *Orbea namaquensis*. Graminoids: *Chaetobromus involucratus* subsp. *dregeanus*, *Ehrharta calycina*.

Biogeographically Important Taxa ([NQ]Namaqualand endemic, [G]Gariep endemic, [R]Richtersveld endemic) Succulent Shrubs: *Aspazoma amplectens*[NQ], *Mitrophyllum clivorum*[NQ], *Phyllobolus deciduus*[G], *P. decurvatus*[NQ], *Ruschia senaria*[R], *Tylecodon buchholzianus* subsp. *buchholzianus*[R], *T.*

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Figure 5.20 SKr 10 Die Plate Succulent Shrubland: Open succulent shrubland with prominent *Aloe pillansii* and *Boscia foetida* (low shrub).

racemosus[NQ]. Woody Climber: *Microloma calycinum*[NQ]. Herb: *Amellus nanus*[G]. Geophytic Herbs: *Bulbine mesembryanthoides* subsp. *namaquensis*[R], *Ornithogalum pruinosum*[NQ]. Succulent Herb: *Mesembryanthemum pellitum*[G].

Conservation Least threatened. Target 28%. None conserved in statutory conservation areas. The area is severely degraded by overgrazing, to such an extent that the original plant communities cannot be recognised anymore; the conservation value of the unit is low.

References Van Jaarsveld (1981), Jürgens (1991, 2004), Jürgens et al. (1997), Van Wyk & Smith (2001).

gummifera, are dominant on rocky outcrops. Large plains of silty or loamy soils are dominated by *Brownanthus pseudoschlichtianus* or by *Zygophyllum prismatocarpum*.

Geology & Soils Metavolcanics and quartzitic metasediments of the De Hoop Subgroup of the Orange River Group account for half the area, with most of the remainder being granite of the Vioolsdrif Suite (both are early Mokolian). Patches of quartzite with a diameter of some metres to several hundred metres embedded within grey granite-gneiss of the Precambrian. Saline loamy soils often underlie the quartz-rich top layers. The almost exclusive land type is Ag.

Climate MAP is 70–120 mm, with winter rainfall predominant. Very few frost days per year and fog plays no important role.

Important Taxa Succulent Shrubs: *Cephalophyllum regale* (d), *Euphorbia gummifera* (d), *Ruschia leucosperma* (d), *Cephalophyllum rigidum*, *Pelargonium crithmifolium*, *Ruschia goodiae*. Low Shrubs: *Fagonia capensis*, *Justicia cuneata* subsp. *latifolia*, *Lessertia falciformis*, *Monechma spartioides, Pteronia glabrata*. Herb: *Dischisma spicatum*. Geophytic Herbs: *Babiana striata* var. *planifolia*, *Crossyne flava*, *Lapeirousia dolomitica* subsp. *dolomitica*, *L. spinosa*, *Ornithogalum nanodes*. Succulent Herbs: *Anacampseros papyracea*, *Crassula columnaris* subsp. *prolifera*, *C. deceptor*.

Biogeographically Important Taxa ([NQ]Namaqualand endemic, [G]Gariep endemic, [R]Richtersveld endemic) Succulent Shrubs: *Aspazoma amplectens*[NQ] (d), *Ruschia paucipetala*[NQ] (d), *Schlechteranthus hallii*[R] (d), *Arenifera pillansii*[R], *Cephalophyllum*

SKr 11 Rooiberg Quartz Vygieveld

VT 33 Namaqualand Broken Veld (100%) (Acocks 1953). LR 56 Upland Succulent Karoo (100%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Richtersveld, region east of Eksteenfontein, south of the Rooiberg and west of the Helskloof Canyon. Altitude ranges from 500–750 m.

Vegetation & Landscape Features Plateau with slightly undulating flats and hills, mosaic of rocky surfaces, loamy and silty-sandy plains and hills covered with quartz layers. Leaf-succulent chamaephytes like *Aspazoma amplectens*, *Cephalophyllum regale, Ruschia leucosperma* and *Schlechteranthus hallii* are dominant on quartz fields, together with highly contracted growth forms such as *Crassula deceptor*, *C. columnaris*, *Cheiridopsis speciosa* and *Euphorbia*

L. Mucina

Figure 5.21 SKr 11 Rooiberg Quartz Vygieveld: Even plains covered by quartz close to the Rooiberg Mountain (visible in the background) near Eksteenfontein (Northern Cape) rich in rare and endemic flora.

goodii[R], *Cheiridopsis herrei*[R], *C. speciosa*[R], *Euphorbia dregeana*[G], *Hoodia alstonii*[G], *Tylecodon bayeri*[R], *Zygophyllum prismatocarpum*[NQ]. Low Shrub: *Berkheya canescens*[G]. Geophytic Herbs: *Adenoglossa decurrens*[NQ], *Tritonia marlothii* subsp. *marlothii*[R]. Succulent Herbs: *Brownanthus pseudoschlichtianus*[G] (d), *Conophytum herreanthus* subsp. *rex*[R].

Endemic Taxa Geophytic Herb: *Tritonia marlothii* subsp. *delpierrei*. Succulent Herb: *Conophytum jucundum* subsp. *fragile*.

Conservation Target 28%. None conserved in statutory conservation areas. Grazing impact and illegal plant collecting due to the easy access are major threats. A number of endemic species, especially within the quartz fields, increase the conservation value of this unit.

Remark Endemic taxa shared with some neighbouring vegetation units include *Arenifera pillansii, Cheiridopsis herrei, Conophytum herreanthus* subsp. *rex* and *Tylecodon bayeri*.

References Van Jaarsveld (1981), Jürgens (1991, 2004), Schmiedel (1994, 2002a, b, 2004), Jürgens et al. (1997), Schmiedel & Jürgens (1999, 2002, 2004), Van Wyk & Smith (2001).

SKr 12 Kosiesberg Succulent Shrubland

VT 33 Namaqualand Broken Veld (79%) (Acocks 1953). LR 56 Upland Succulent Karoo (99%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Southwestern Richtersveld—a major part of the mountain ranges and escarpment region stretching 55 km from Eksteenfontein in the north over the slopes of the Kosiesberg to the Anenous Pass in the southeast. Altitude varies from about 500–1 100 m.

Vegetation & Landscape Features Escarpment that includes the steep slope between the high plateau in the east and the lower plateau in the west as well as several ranges of mountains and hills at the upper and lower level. Due to the incision of deep valley systems, the area is deeply dissected into a number of thinly connected fragments. A number of the plant communities found in the SKr 1 Central Richtersveld Mountain Shrubland, also occur here (Jürgens 2004).

Geology & Soils Granite and gneiss of the Mokolian Hoogoor and Vioolsdrif Suites are most significant, but a large area in the west is underlain by Namaqua System alkali-granite of the Korridor Suite. These rocks support mostly loamy soils. Ib land type is dominant, followed by Ic land type.

Climate MAP is estimated at 100–200 mm (and possibly slightly higher). Winter rainfall is clearly predominant. Orogenic cloud formation and fog are frequently observed in winter. At higher altitudes up to 10 frost days per year can be expected.

Important Taxa ([A]At higher altitudes) Succulent Shrubs: *Didelta spinosa*[A] (d), *Euphorbia mauritanica* (d), *Othonna furcata*[A] (d), *Tylecodon paniculatus* (d), *Cheiridopsis namaquensis*, *Cotyledon orbiculata* var. *orbiculata*, *Euphorbia gummifera*, *E. hamata*, *Zygophyllum foetidum*[A]. Tall Shrubs: *Montinia caryophyllacea*[A] (d), *Rhus populifolia* (d), *R. incisa*. Low Shrubs: *Elytropappus rhinocerotis*[A] (d), *Euryops tenuissimus*[A] (d), *Galenia africana* (d), *Senecio haworthii*[A]. Semiparasitic Epiphytic Shrub: *Moquiniella rubra*. Geophytic Herbs: *Babiana truncata*, *Haemanthus crispus*, *H. namaquensis*, *Hesperantha pauciflora*, *Hessea breviflora*, *Lachenalia bolusii*, *L. violacea*, *Moraea tortilis*, *Strumaria truncata*, *S. villosa*, *Syringodea longituba*, *Tulbaghia dregeana*.

Biogeographically Important Taxa ([NQ]Namaqualand endemic, [G]Gariep endemic, [R]Richtersveld endemic) Succulent Shrubs: *Ruschia senaria*[R] (d), *Zygophyllum prismatocarpum*[NQ] (d), *Aloe dichotoma* var. *ramosissima*[G], *Ceraria fruticulosa*[G], *Cheiridopsis denticulata*[NQ], *C. herrei*[R], *C. speciosa*[R], *Phyllobolus deciduus*[G], *Tylecodon bayeri*[R], *Zygophyllum leptopetalum*[NQ]. Geophytic Herbs: *Geissorhiza namaquensis*[NQ], *Haemanthus unifoliatus*[NQ], *Lachenalia carnosa*[NQ], *Moraea herrei*[NQ]. Succulent Herbs: *Brownanthus pseudoschlichtianus*[G] (d), *Conophytum herreanthus* subsp. *rex*[R], *Crassula grisea*[G].

Endemic Taxon Succulent Shrub: *Mitrophyllum dissitum*.

Conservation Least threatened. Target 28%. None conserved in statutory conservation areas. Not transformed, but the major threat is the expansion of small stock farming, especially at the northern and southern ends of the unit. A major part is relatively protected due to the steep and inaccessible landscape. The unit is not well studied and includes a large number of species, including rare and endemic ones. Therefore, parts of the unit, including at least a part of the escarpment slopes, should be conserved.

Remark 1 The unit is characterised by high beta diversity due to steep altitudinal gradients and mountainous topography. *Conophytum herreanthus* subsp. *herreanthus* occurs at Klipbok (within the unit) but also within SKr 16 Umdaus Mountains Succulent Shrubland. *Cheiridopsis speciosa* and *Tylecodon bayeri* are also found towards SKr 11 Rooiberg Quartz Vygieveld. Although the summit of Kosiesberg is mapped just outside this unit, its main escarpment represents this unit.

Remark 2 Due to the lower temperatures and possibly higher rainfall, this shrubland shows some important differences from the SKr 1 Central Richtersveld Mountain Shrubland. Generally, it has a higher proportion of tall and dense shrublands (partly higher than 2 m), with communities quite similar to the dominant vegetation of the SKn 1 Namaqualand Klipkoppe Shrubland, with a group of communities dominated by *Didelta spinosa* and associated with *Tylecodon paniculatus, Montinia caryophyllacea, Othonna furcata* and *Galenia africana*. A large number of species that do not occur (or are only rarely seen) in the SKr 1 Central Richtersveld Mountain Shrubland occur here; these include especially geophytes of the genera *Babiana, Haemanthus, Hesperantha, Hessea, Lachenalia, Strumaria, Syringodea* and *Tulbaghia*.

References Van Jaarsveld (1981), Jürgens (1991, 2004), Jürgens et al. (1997), Van Wyk & Smith (2001).

SKr 13 Southern Richtersveld Scorpionstailveld

VT 31 Succulent Karoo (70%) (Acocks 1953). LR 57 Lowland Succulent Karoo (62%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Southern Richtersveld—large portion of the plains west of the Anenous Pass, stretching over some 55 km to Oograbies in the west and from Skimmelberg in the north to just south of the road connecting Steinkopf and Port Nolloth. Altitude is mainly 200–600 m.

Vegetation & Landscape Features Flat basin landscape with a number of inselbergs embedded (mapped as SKr 14 Southern Richtersveld Inselberg Shrubland). Generally the low vegetation is dominated by the flat cushions of *Brownanthus pseudoschlichtianus*. Towards the west, a strong admixture of grasses, or mosaic elements of grassland, accompany the (flat) transition to SKs 6 Oograbies Plains Sandy Grassland. Towards the escarpment, increasing rainfall and grazing pressure result in increasing importance of *Zygophyllum retrofractum*. In degraded

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Figure 5.22 SKr 13 Southern Richtersveld Scorpionstailveld: Succulent shrublands with *Brownanthus pseudoschlichtianus* west of Steinkopf on the road to Port Nolloth (Northern Cape).

areas *Lebeckia multiflora* and/or *Euphorbia ephedroides* are important.

Geology & Soils Silts and loamy sands of partly aeolian origin above migmatite and gneiss of the Namaqualand Metamorphic Complex (Precambrian age). Ae land type is dominant, followed by Ag land type.

Climate MAP is estimated at 80–140 mm, with winter rainfall clearly predominant. Frost is very rare. Fog and high air humidity often occur. Southerly winds are stronger in the west of the unit. See also climate diagram for SKr 13 Southern Richtersveld Scorpionstailveld (Figure 5.12).

Important Taxa Succulent Shrubs: *Euphorbia ephedroides* var. *ephedroides* (d), *Aridaria serotina*, *Cheiridopsis robusta*, *Drosanthemum inornatum*, *Eberlanzia dichotoma*, *Hypertelis salsoloides*, *Lampranthus otzenianus*, *Leipoldtia laxa*, *L. schultzei*, *L. uniflora, Psilocaulon subnodosum*, *Ruschia goodiae*. Low Shrub: *Lebeckia multiflora* (d). Herbs: *Grielum humifusum*, *Leysera tenella*, *Plantago cafra*. Geophytic Herbs: *Ophioglossum polyphyllum*, *Trachyandra muricata*. Succulent Herb: *Conicosia pugioniformis* subsp. *alborosea*.

Biogeographically Important Taxa ([NQ]Namaqualand endemic, [G]Gariep endemic) Succulent Shrubs: *Eberlanzia cyathiformis*[G], *Phyllobolus deciduus*[G]. Geophytic Herb: *Oxalis copiosa*[NQ]. Succulent Herb: *Brownanthus pseudoschlichtianus*[G] (d).

Conservation Least threatened but in reality susceptible. Target 28%. None conserved in statutory conservation areas. Evidence of overgrazing and trampling leading to erosion and to disturbance of topsoil occurs. High cover of *Lebeckia multiflora* and *Euphorbia ephedroides* in many parts of this unit might be indicative of a shift towards a higher proportion of weeds, when heavily grazed.

References Van Jaarsveld (1981), Jürgens (1991, 2004), Jürgens et al. (1997).

SKr 14 Southern Richtersveld Inselberg Shrubland

VT 31 Succulent Karoo (72%) (Acocks 1953). LR 57 Lowland Succulent Karoo (70%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Southern Richtersveld—inselbergs scattered over the plains between Anenous Pass and Port Nolloth, partly surrounded by patches of SKr 13 Southern Richtersveld Scorpionstailveld. Includes Klaarkop, Kabies se Berg, Rooidam se Koppe, Steenbok se Berge and Beesvlei se Berg (but excludes the unique Vyftienmyl se Berge inselbergs). Altitude varies from about 100–600 m.

Vegetation & Landscape Features The inselbergs differ markedly in size, altitude, steepness, rockiness and spatial aggregation. Habitats vary depending on exposure, altitude and soil type. Smaller inselbergs are considerably more arid than higher ones, with lower parts covered by sparse chamaephyte vegetation, often dominated by the nanophanerophyte *Zygophyllum prismatocarpum*. At higher altitudes, especially on southwest-facing slopes, dense vegetation of dwarf leaf-succulents and lichens occurs.

Geology & Soils Granite, gneiss and schist mostly of the Gladkop and Hoogoor Suites (Mokolian) that were affected by the Namaqualand metamorphic event. Shallow soils of mostly loamy sand. Almost 75% of the area is Ag land type, followed by Ib.

Climate MAP estimated at 80–150 mm, with winter rainfall clearly predominant. The importance of fog is high in the west and decreases towards the east. Frost is very rare. See also climate diagram for SKr 14 Southern Richtersveld Inselberg Shrubland (Figure 5.12).

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Figure 5.23 SKr 14 Southern Richtersveld Inselberg Shrubland: Shrubland dominated by *Stoeberia frutescens* (Aizoaceae) on the slopes of an inselberg on the Farm Aardvark (east of Port Nolloth, Northern Cape).

Important Taxa Succulent Shrubs: *Drosanthemum floribundum* (d), *D. inornatum* (d), *Stoeberia frutescens* (d), *Adromischus mammillaris*, *A. marianiae* var. *immaculatus*, *Cheiridopsis robusta*, *Cotyledon orbiculata* var. *orbiculata*, *Eberlanzia gravida*, *Euphorbia decussata*, *E. hamata*, *E. mauritanica*, *Hypertelis salsoloides*, *Kleinia longiflora*, *Octopoma connatum*, *Pelargonium crithmifolium*, *Psilocaulon subnodosum*, *Ruschia intricata*, *Salsola namibica*, *S. zeyheri*, *Sarcocaulon l'heritieri*, *Senecio sarcoides*, *Tetragonia fruticosa*, *Tylecodon paniculatus*. Tall Shrubs: *Montinia caryophyllacea*, *Rhus populifolia*. Low Shrubs: *Dyerophytum africanum*, *Galenia fruticosa*, *Helichrysum asperum* var. *albidulum*, *Lebeckia sericea*, *Pteronia glomerata*, *Tripteris oppositifolia*. Succulent Herbs: *Conophytum chrisocruxum*, *C. meyeri*, *Crassula columnaris* subsp. *prolifera*, *C. muscosa*, *Mesembryanthemum guerichianum*, *Senecio cicatricosus*, *Tromotriche aperta*. Graminoids: *Enneapogon scaber* (d), *Fingerhuthia africana*, *Stipagrostis zeyheri* subsp. *macropus*.

Biogeographically Important Taxa ([NQ]Namaqualand endemic, [G]Gariep endemic, [R]Richtersveld endemic, [N]Northern distribution limit, [W]Western distribution limit) Succulent Shrubs: *Stoeberia frutescens*[NQ] (d), *Zygophyllum prismatocarpum*[NQ] (d), *Euphorbia dregeana*[G], *Hallianthus planus*[NQ], *Schlechteranthus maximilianii*[R], *Tetragonia robusta* var. *psiloptera*[N]. Low Shrub: *Hermbstaedtia glauca*[G]. Herb: *Gorteria corymbosa*[G]. Succulent Herbs: *Conophytum obscurum* subsp. *obscurum*[R], *Crassula grisea*[G], *Huernia namaquensis*[NQ], *Larryleachia cactiformis* var. *cactiformis*[W].

Endemic Taxa Succulent Shrubs: *Euphorbia ephedroides* var. *debilis*, *Namaquanthus vanheerdii*, *Polymita steenbokensis*, *Tylecodon cordiformis*. Succulent Herb: *Crassula alstonii*.

Conservation Least threatened. Target 28%. None conserved in statutory conservation areas. The inselbergs house a number of endemic species and should receive protection status. Besides small stock grazing there is no specific threat.

Remark Compared to the SKr 5 Vyftienmyl se Berge Succulent Shrubland, these few major inselbergs or ridges at similar altitude lie further inland and are, therefore, less exposed to the coastal fog.

References Van Jaarsveld (1981), Jürgens (1991, 2004), Jürgens et al. (1997), Van Wyk & Smith (2001).

SKr 15 Anenous Plateau Shrubland

VT 33 Namaqualand Broken Veld (97%) (Acocks 1953). LR 56 Upland Succulent Karoo (91%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Anenous Plateau (west of the Steinkopf Plateau) in the southeastern Richtersveld, and parts of the adjacent escarpment, extending some 15 km to the north and to the south of the Anenous Pass. Region includes mountains such as Narraberg and Klipfonteinberg. Altitude ranges from 500–1 100 m with most of the unit 700–1 000 m.

Vegetation & Landscape Features High plateau with some rolling hills and larger mountains. The original dense shrubland is now fragmented and confined to mountains and to rocky areas. On the plains, the former shrubland is found only as dense bush patches around rocky outcrops. Flat rocky areas also support vegetation dominated by leaf-succulent dwarf shrubs. On deeper soils on the plains, old fields and heavily grazed areas show a dominance of annual herbs and geophytes.

Geology & Soils Gneiss and schist of the Precambrian Namaqualand Metamorphic Complex. Soils are mostly loamy sands and loams. Almost the entire area falls within Fb land type.

Climate Mild to cool winter-rainfall climate. MAP ranges in most of the area from 120–160 mm. Most of the area experiences up to 10 frost days per year. See also climate diagram for SKr 15 Anenous Plateau Shrubland (Figure 5.12).

Important Taxa Succulent Tree: *Aloe dichotoma* var. *dichotoma*. Succulent Shrubs: *Didelta spinosa* (d), *Othonna furcata* (d), *Tylecodon paniculatus* (d), *Aloe microstigma*, *Drosanthemum hispidum*, *Euphorbia mauritanica*, *Lampranthus otzenianus*, *L. watermeyeri*, *Manochlamys albicans*, *Psilocaulon subnodosum*, *Zygophyllum foetidum*. Tall Shrubs: *Rhus incisa* (d), *R. populifolia*. Low Shrubs: *Euryops tenuissimus* (d), *Galenia africana* (d), *Elytropappus rhinocerotis*, *Pteronia divaricata*, *Senecio haworthii*. Semiparasitic Shrub: *Thesium lineatum*. Herbs: *Arctotis fastuosa* (d), *Dimorphotheca sinuata* (d), *Grielum humifusum*, *Leysera tenella*. Geophytic Herbs: *Albuca maxima*, *Brunsvigia herrei*, *Gethyllis britteniana* subsp. *britteniana*, *Haemanthus crispus*, *Lachenalia violacea*, *Moraea brevituba*, *M. rivulicola*, *Strumaria truncata*, *Trachyandra muricata*. Succulent Herb: *Conicosia pugioniformis* subsp. *alborosea*.

Biogeographically Important Taxa ([NQ]Namaqualand endemic, [G]Gariep endemic) Succulent Shrubs: *Cheiridopsis denticulata*[NQ], *Eberlanzia cyathiformis*[G], *Hallianthus planus*[NQ], *Prenia pallens* subsp. *namaquensis*[NQ], *Zygophyllum leptopetalum*[NQ]. Geophytic Herb: *Lachenalia carnosa*[NQ]. Succulent Herb: *Cleretum papulosum* subsp. *schlechteri*[NQ].

Conservation Least threatened. Target 28%. None conserved in statutory conservation areas. Apparently little transformed

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Figure 5.24 SKr 15 Anenous Plateau Shrubland: Species-rich succulent shrublands on the Anenous Pass (west of Steinkopf).

judging from land-cover satellite information. However, field evidence shows that strong grazing pressure has dramatically changed the face of this landscape. Most of the landscape forms open grazing ground for stock and ploughed land is frequently seen. This suggests endangered status combined with a moderate risk of erosion (more than 90% classified as moderate erosion). The target conservation percentage of the unit should include part of the mountains and the escarpment.

Remark This unit includes some of the wettest flat areas in the Richtersveld due to mild temperatures and orogenic rains caused by the escarpment. The unit is not well studied and the boundaries (especially the inclusion of parts of the escarpment) are based on a limited number of observations.

References Van Jaarsveld (1981), Jürgens (1991, 2004), Jürgens et al. (1997), Van Wyk & Smith (2001).

SKr 16 Umdaus Mountains Succulent Shrubland

VT 33 Namaqualand Broken Veld (70%) (Acocks 1953). LR 56 Upland Succulent Karoo (75%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Area between the Steinkopf Plateau and the Nababeep Mountains in the south-eastern Richtersveld including the wide basins of the Wyepoort and Aribes Rivers. The eastern margin is not well defined and is mapped just short of Geelberg. Altitude ranges from about 500–1 000 m.

Vegetation & Landscape Features Mountainous terrain along the southern and western edges and sheet wash plains with roundish or steep rocky hills. While most of the unit is characterised by various Succulent Karoo plant communities, towards the northern and eastern margin Nama-Karoo elements are increasingly important. Mainly exposure and soil type define the habitat types with a variety of vegetation units, including rocky outcrops with *Aloe dichotoma*, *Euphorbia dregeana*, *Pachypodium namaquanum* and *Sarcostemma viminale*, loamy plains with *Brownanthus pseudoschlichtianus*, calcrete plains with *Stomatium alboroseum* and quartz patches with *Polymita albiflora*.

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Figure 5.25 SKr 16 Umdaus Mountains Succulent Shrubland: Sparse succulent shrubland on granite sheet outcrops north of Steinkopf. Shrublands belonging to the vegetation unit SKr 17 Eenriet Plains Succulent Shrubland are visible in the background.

Geology & Soils Mainly Mokolian granites, gneisses and schists supporting shallow soils of loamy or sandy texture. Ib land type dominates the landscapes.

Climate Mainly winter rainfall with slight transition to summer rainfall in the east. Estimated MAP 100–200 mm. Up to 10 frost days per year. Fog not important. See also climate diagram for SKr 16 Umdaus Mountains Succulent Shrubland (Figure 5.12).

Important Taxa Succulent Tree: *Aloe dichotoma* var. *dichotoma*. Succulent Shrubs: *Ruschia robusta* (d), *Tetragonia arbuscula* (d), *Arenifera stylosa*, *Cephalophyllum rigidum*, *Cheiridopsis namaquensis*, *Euphorbia mauritanica*, *Hoodia gordonii*, *Leipoldtia schultzei*, *Pelargonium crithmifolium*, *Salsola namibica*, *Zygophyllum dregeanum*, *Z. lichtensteinianum*. Tall Shrubs: *Cadaba aphylla*, *Nymania capensis*, *Rhus populifolia*. Low Shrubs: *Galenia fruticosa* (d), *Aptosimum spinescens*, *Berkheya fruticosa*, *Dyerophytum africanum*, *Hermannia stricta*, *Limeum aethiopicum*, *Microloma incanum*, *Monechma spartioides*, *Osteospermum karrooicum*, *Petalidium parvifolium*, *Pharnaceum dichotomum*, *Polygala leptophylla*, *Pteronia ambrariifolia*, *Sericocoma avolans*, *Zygophyllum retrofractum*. Semiparasitic Shrubs: *Thesium hystrix*, *T. lineatum*. Woody Succulent Climber: *Sarcostemma viminale*. Herbs: *Chascanum garipense* (d), *Codon royenii*, *Dianthus namaensis* var. *dinteri*, *Osteospermum pinnatum*. Geophytic Herbs: *Brunsvigia namaquana*, *B. radula*, *Hessea breviflora*, *Moraea saxicola*. Succulent Herbs: *Conophytum herreanthus* subsp. *herreanthus*, *Crassula deceptor*, *C. muscosa*, *Haworthia venosa* subsp. *tessellata*. Parasitic Herb: *Hyobanche glabrata*. Graminoids: *Aristida adscensionis* (d), *Stipagrostis obtusa* (d), *Enneapogon desvauxii*, *E. scaber*, *Stipagrostis brevifolia*.

Biogeographically Important Taxa ([NQ]Namaqualand endemic, [G]Gariep endemic, [R]Richtersveld endemic) Succulent Tree: *Pachypodium namaquanum*[G]. Small Tree: *Ozoroa concolor*[NQ]. Succulent Shrubs: *Ceraria namaquensis*[G] (d), *Cheiridopsis denticulata*[NQ] (d), *Polymita albiflora*[NQ] (d), *Cheiridopsis herrei*[R], *C. schlechteri*[G], *Euphorbia dregeana*[G], *Hoodia alstonii*[G], *Ruschia paucipetala*[NQ], *Stoeberia frutescens*[NQ], *Stomatium alboroseum*[NQ]. Tall Shrub: *Calliandra redacta*[G]. Low Shrubs: *Hermbstaedtia glauca*[G], *Pelargonium spinosum*[G]. Succulent Herbs: *Brownanthus pseudoschlichtianus*[G] (d), *Larryleachia perlata*[R].

Endemic Taxa Succulent Shrub: *Tylecodon pusillus*. Succulent Herb: *Anacampseros pisina*.

Conservation Least threatened. Target 28%. None conserved in statutory conservation areas. A number of rare, interesting and a few endemic species point to a relatively high conservation value. The expansion of small stock farming from the south and southwest and a few mining activities in the eastern region of the unit are viewed as main threats.

Remark This vegetation unit is of special interest as it forms an overlap of climate and floristic elements of East Gariep and Succulent Karoo. It includes the southernmost populations of the East Gariep element *Pachypodium namaquanum*.

References Van Jaarsveld (1981), Jürgens (1991, 2004), Jürgens et al. (1997), Van Wyk & Smith (2001).

SKr 17 Eenriet Plains Succulent Shrubland

VT 33 Namaqualand Broken Veld (57%) (Acocks 1953). LR 49 Bushmanland Nama Karoo (41%), LR 56 Upland Succulent Karoo (30%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Plains northwest of Kabinaberg and south of the Koubank River, extending west and east of the main road between Steinkopf and Vioolsdrif, in the southeastern Richtersveld, partly forming the transition to Bushmanland. Altitude varies from ca. 650 m in the north to 950 m in the south.

Vegetation & Landscape Features Wide plains tilting towards the north, with few inselbergs. The extensive plains often resemble sheet wash plains. The deep loamy-sandy soils support mostly dense shrubby vegetation dominated by *Ruschia paucipetala*, *Prenia tetragona* or *Brownanthus pseudoschlichtianus*. *Stomatium alboroseum* and *Polymita albiflora* are found on calcrete or quartz patches. On the inselberg rocky outcrops numerous isolated populations of some Crassulaceae (e.g. *Crassula macowaniana* and *Tylecodon racemosus*) are found.

Geology & Soils Fine-structured deep loamy sands over gneiss of the Precambrian Namaqualand Metamorphic Complex. Ag land type dominates.

Climate Winter-rainfall regime, but with some summer rainfall also occurring (mainly March), especially towards the eastern boundaries of the unit. MAP was estimated at 100–160 mm. Some 10 to 20 frost days occur per year. See also climate diagram for SKr 17 Eenriet Plains Succulent Shrubland (Figure 5.12).

Important Taxa Succulent Shrubs: *Ruschia leucosperma* (d), *Drosanthemum floribundum*, *Euphorbia ephedroides* var. *ephedroides*, *E. friedrichiae*, *Lampranthus otzenianus*, *Leipoldtia schultzei*, *Odontophorus nanus*, *Pelargonium echinatum*, *Prenia tetragona*, *Sarcocaulon herrei*. Geophytic Herbs: *Hessea pilosula, Lachenalia violacea*. Succulent Herb: *Piaranthus cornutus*. Graminoids: *Stipagrostis ciliata*, *S. obtusa*.

Biogeographically Important Taxa ([NQ]Namaqualand endemic, [G]Gariep endemic, [R]Richtersveld endemic) Succulent Shrubs: *Ruschia paucipetala*[NQ] (d), *Cheiridopsis herrei*[R], *C. schlechteri*[G], *Polymita albiflora*[NQ], *Stomatium alboroseum*[NQ], *Tylecodon pearsonii*[NQ], *T. racemosus*[NQ]. Herb: *Gorteria corymbosa*[G]. Succulent Herbs: *Brownanthus pseudoschlichtianus*[G] (d), *Mesembryanthemum barklyi*[NQ].

Endemic Taxon Geophytic Herb: *Ornithogalum unifoliatum*.

Conservation Least threatened. Target 28%. None conserved in statutory conservation areas. No obvious major threats. Small stock grazing is of low intensity. An analysis of the biodiversity of the inselbergs is recommended.

Remark This unit has characters that are intermediate between Succulent Karoo and Nama-Karoo with respect to biogeographical patterns and to growth form composition.

References Van Jaarsveld (1981), Jürgens (1991, 2004), Jürgens et al. (1997), Van Wyk & Smith (2001).

SKr 18 Bushmanland Inselberg Shrubland

VT 29 Arid Karoo and Desert False Grassveld (49%), VT 33 Namaqualand Broken Veld (33%) (Acocks 1953). LR 49 Bushmanland Nama Karoo (70%) (Low & Rebelo 1996).

Distribution Northern Cape Province: A group of prominent solitary mountains (inselbergs) and smaller koppies towering over surrounding flat plains in northern Bushmanland in the Aggeneys and Pofadder regions. The most important inselbergs include Achab se Berg, Aggeneys se Berg, Ghaamsberg, Goob se Berg, Naib se Berg and Namiesberge. Altitude ranges from 600–1 180 m (most of the area 700–1 120 m).

Vegetation & Landscape Features Shrubland with both succulent (Aizoaceae, Asphodelaceae, Crassulaceae, Didiereaceae, Euphorbiaceae, Zygophyllaceae) as well as nonsucculent (mainly Asteraceae) elements and with sparse grassy undergrowth (*Aristida, Eragrostis, Stipagrostis*) on steep slopes of the inselbergs.

Geology & Soils Inselbergs of high-grade metamorphic rocks on a broad alluvial plain consist of clastic sediments, volcanics and intrusive rocks of Mokolian age that were metamorphosed during the Namaqualand Metamorphic Event. Ib and Ic land types are dominant in the area.

Climate Erratic, very low rainfall (MAP below 100 mm, range 70–120 mm) occurring mainly in the form of thunderstorms in late summer from February to April. Around 20 days of frost per year (range 10–30 days). Mean maximum and minimum mean monthly temperatures for Aggeneys are 38°C and –3°C for February and July, respectively. See also climate diagram for SKr 18 Bushmanland Inselberg Shrubland (Figure 5.12).

Important Taxa Succulent Shrubs: *Adromischus diabolicus* (d), *Euphorbia gregaria* (d), *Ihlenfeldtia vanzylii* (d), *Ruschia divaricata* (d), *Schwantesia pillansii* (d), *Tylecodon sulphureus* (d), *Euphorbia gariepina*, *Kleinia longiflora*, *Othonna euphorbioides*, *Psilocaulon subnodosum, Tetragonia reduplicata*, *Tylecodon rubrovenosus*. Tall Shrub:

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Figure 5.26 SKr 17 Eenriet Plains Succulent Shrubland: Succulent shrublands with *Ruschia pauciflora* (in the foreground) and *Sisyndite spartea* (in the background).

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Figure 5.27 SKr 18 Bushmanland Inselberg Shrubland: South-facing slopes of Naip se Berg inselberg in northern Bushmanland with *Euphorbia gregaria* and *Cotyledon orbiculare*. Note the sparse vegetation on hot north-facing slopes in the background.

Boscia foetida. Low Shrubs: *Eriocephalus pauperrimus* (d), *Pteronia unguiculata*. Woody Succulent Climber: *Sarcostemma viminale* (d). Herb: *Acanthopsis hoffmannseggiana*. Succulent Herbs: *Anacampseros baeseckei* (d), *A. karasmontana* (d), *Avonia ruschii* (d), *Conophytum fulleri* (d), *Avonia quinaria* subsp. *alstonii*, *Conophytum marginatum* var. *haramoepense*. Graminoids: *Aristida adscensionis* (d), *Eragrostis annulata*, *Stipagrostis obtusa*.

Biogeographically Important Taxa ([NQ]Namaqualand endemic, [G]Gariep endemic) Succulent Shrubs: (d), *Ceraria fruticulosa*[G], *Cheiridopsis pillansii*[G]. Geophytic Herb: *Whiteheadia bifolia*[NQ]. Succulent Shrub: *Hoodia alstonii*[G].

Endemic Taxon Succulent Herb: *Huernia barbata* subsp. *ingeae*.

Conservation Threatened (although not immediately) by potential mining interests around Aggeneys. Target 34%. None conserved in statutory conservation areas—a fact needing quick remedy. Erosion is very low.

Remark The vegetation of this unit is of extrazonal nature—a unit of Succulent Karoo embedded within a region with transitional winter/summer-rainfall regime of the surrounding NKb 3 Bushmanland Arid Grassland. The major motivation for the classification of the Bushmanland Inselberg Shrubland (as well as the associated SKr 19 Aggeneys Gravel Vygieveld, see below) is based on special substrate-generating conditions for dominance of (dwarf) succulent flora. There is also a very tight topographic link to the Desert Biome: while the Succulent Karoo unit occurs on the climatically more favourable southern aspect, the northern slopes of the same inselbergs host the Dg 9 East Gariep Rocky Desert vegetation. The inselbergs support a high number of local endemics, especially succulents of the families Aizoaceae, Apocynaceae, Crassulaceae as well as some interesting Portulacaceae (*Avonia, Anacampseros*) and closely related Didiereaceae (*Ceraria*).

References Anderson & Van Heerden (2000), Desmet (2000a, b), Fick (2000), Hammer (2002).

SKr 19 Aggeneys Gravel Vygieveld

VT 33 Namaqualand Broken Veld (92%) (Acocks 1953). LR 51 Orange River Nama Karoo (83%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Plains at foothills or on peneplains of inselbergs in northern Bushmanland scattered between Pofadder and Aggeneys and further westwards to the edges of the Namaqualand granite hill ridges. Altitude: mainly 840–1 060 m.

Vegetation & Landscape Features Flat or slightly sloping plains (appearing as distinctly white surface quartz layers against the background of red sand or reddish soil) and supporting sparse, low-growing vegetation dominated by small to dwarf leaf-succulents of the families Aizoaceae, Crassulaceae, Euphorbiaceae, Portulacaceae and Zygophyllaceae, with some perennial component. The resurrection grass *Eragrostis nindensis* is the dominant perennial graminoid.

Geology & Soils Gneiss of the Little Namaqualand and Hoogoor Suites, and quartzite of the Bushmanland and Geelvloer Groups dominate. The occurrence of these two broad geological groups is the primary determinant of the location of the different types of gravel patches usually found at the foothills or on peneplains associated with the base of inselbergs or low ridges amongst the gently undulating plains. In places rare feldspar patches occur, always associated with the pink gneiss of the Hoogoor Suite. Four types of gravel patches are encountered in the area: (1) fine-grained quartz patches with a uniform covering of small diameter (<1 cm) quartz pebbles occur on the summits and foothills of some inselbergs (e.g. Gamsberg and Achab), (2) quartz gravel patches with more variable size-class distribution occurring more widely, but generally associated with the foothills of the quartzite inselbergs of the region, (3) feldspar gravel patches associated with open plains with underlying gneiss geology, and (4) calcrete gravel patches occurring on open plains, where the topsoil and dorbank of the colluvial soils have been eroded, exposing the underlying calcrete layer. The soils are very shallow, skeletal and loamy-sandy. Ag land type covers half of the area, followed by Ic and Af land types.

Climate Overall climatic characters are largely identical (or very similar) to those listed for the topographically neighbouring SKr 18 Bushmanland Inselberg Shrubland. See also climate diagram for SKr 19 Aggeneys Gravel Vygieveld (Figure 5.12).

Important Taxa Small Tree: *Boscia albitrunca*. Succulent Shrubs: *Ruschia divaricata* (d), *Euphorbia gariepina*, *E. gregaria*, *E. mauritanica*, *Hypertelis salsoloides*, *Kleinia longiflora*, *Lycium cinereum*, *Psilocaulon subnodosum*, *Sarcocaulon crassicaule*, *Senecio sarcoides*, *Titanopsis hugo-schlechteri*. Low Shrubs: *Pegolettia retrofracta* (d), *Aptosimum spinescens*, *Eriocephalus ambiguus*, *Euphorbia spinea*, *Fagonia capensis, Galenia fruticosa*, *Helichrysum pumilio* subsp. *pumilio*, *Hermannia spinosa*, *Microloma incanum*, *Monechma spartioides*. Succulent Herbs:

Crassula corallina subsp. *macrorrhiza*, *C. deltoidea*. Graminoid: *Stipagrostis ciliata*.

Biogeographically Important Taxa ([NQ]Namaqualand endemic, [G]Gariep endemic) Succulent Shrubs: *Antimima vanzylii*[G] (d), *Ceraria fruticulosa*[G], *C. namaquensis*[G], *Stomatium alboroseum*[NQ]. Low Shrub: *Berkheya canescens*[G]. Succulent Herbs: *Anacampseros filamentosa* subsp. *namaquensis*[NQ], *Avonia papyracea* subsp. *namaensis*[G], *A. papyracea* subsp. *papyracea*[G], *Crassula sericea* var. *sericea*[G], *Mesembryanthemum inachabense*[G], *Phyllobolus latipetalus*[G]. Herb: *Adenoglossa decurrens*[NQ].

Endemic Taxa Succulent Shrubs: *Adromischus nanus*, *Dinteranthus puberulus*, *D. vanzylii*, *Lapidaria margaretae*. Succulent Herbs: *Anacampseros bayeriana*, *Conophytum achabense*, *C. angelicae* subsp. *angelicae*, *C. burgeri*, *C. calculus* subsp. *vanzylii*, *C. friedrichiae*, *C. limpidum*, *C. lydiae*, *C. maughanii*, *C. praesectum*, *C. ratum*, *Lithops dorotheae*, *L. julii* subsp. *fulleri*.

Conservation The unit features as least threatened and none is conserved in statutory conservation areas. The conservation target was set at 18%. Due to low vegetation cover, the gravel patches are not targeted for grazing. No serious alien-plant incursions have been observed since the soil surface does not suffer disturbance injuries—consequently erosion is very low.

Remark 1 The gravel patches of northern Bushmanland are not as well defined in the landscape as those in other parts of the Succulent Karoo Biome. There are probably more gravel patches of considerable extent in the region of Pofadder and Aggeneys than what we are featuring on our vegetation map. The unit also occurs in southern Namibia in the Warmbad region. The low precipitation regime of the northern Bushmanland explains why the biomass of plants occurring on the gravel patches is very low in comparison to the floristically related and more mesic gravel patches of the Little Karoo or Knersvlakte. Floristically and structurally the Aggeneys Gravel Vygieveld can be considered a true Succulent Karoo vegetation type and thus, in conjunction with that found on the steep southern slopes of the larger inselbergs, forms the easternmost extent of the Succulent Karoo Biome in Bushmanland. Except for a small pocket of this vegetation on the Naip se Berg inselberg (halfway between Springbok and Aggeneys), this enclave of the Succulent Karoo vegetation is isolated from the main body of this vegetation in Namaqualand (that finds its limits in the area of Smorenskadu and Kangnas) by the sandy plains covered with NKb 3 Bushmanland Arid Grassland.

Remark 2 Two endemic genera, *Dinteranthus* and *Lapidaria* (both Aizoaceae), occur in the Warmbad-Aggeneys gravel patches. *Schwantesia* (also Aizoaceae) has a distinct centre of diversification in this unit.

References Desmet (2000a, b), Fick (2000), Hammer (2002), Schmiedel (2002a, b).

Namaqualand Hardeveld

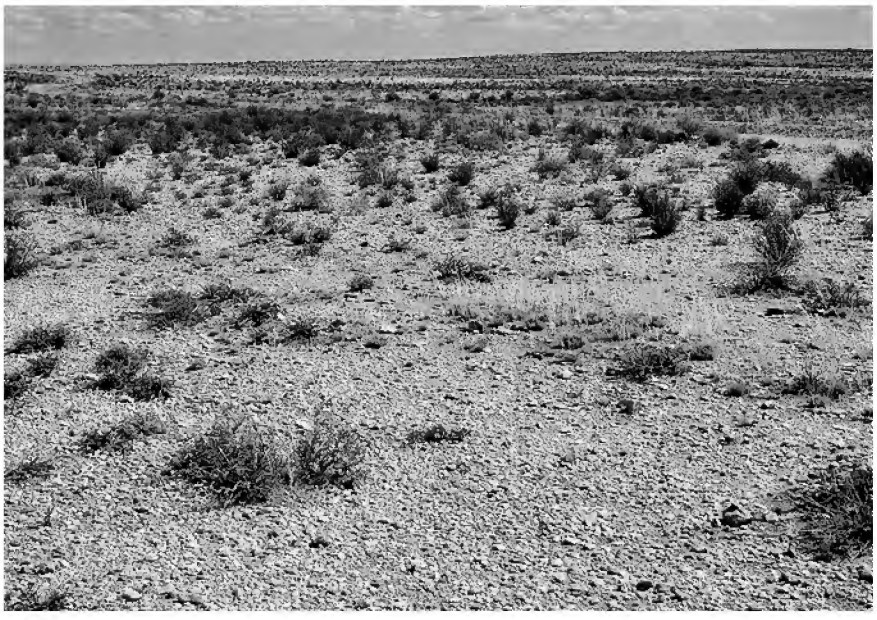
SKn 1 Namaqualand Klipkoppe Shrubland

VT 33 Namaqualand Broken Veld (65%) (Acocks 1953). LR 56 Upland Succulent Karoo (73%) (Low & Rebelo 1996).

Distribution Northern and Western Cape Provinces: Central and north-central regions of Namaqualand spanning Steinkopf in the north and Nuwerus in the south. Altitude 120–1 260 m.

Vegetation & Landscape Features Dramatic landscape of huge granite and gneiss domes, smooth glacis and disintegrating boulder koppies supporting open shrubland up to 1 m tall, dominated by shrubs of dwarf to medium stature and with ericoid or succulent leaves. A few scattered pachycaul kokerboom trees (*Aloe dichotoma* var. *dichotoma*) are found mostly on north-facing slopes. Flat or gently sloping rock sheets (the dominant feature of this unit) support dwarf or prostrate succulents in shallow pockets with soil or in cracks. Fringe vegetation at the bottom of steep rock sheets (collecting run-off water) consists of 1–3 m tall shrubs with nonsucculent leaves and canopy cover reaching 40–100%.

Geology & Soils A number of Mokolian granites and gneisses (most widespread is the Kamieskroon Gneiss) form gentle to moderate rocky slopes, rock sizes varying from medium to large with flat to gentle rock sheets as well as rock domes, yellow-brown to brown loamy sand, 0.15–0.6 m deep. Ag and Ib land types (35% each), followed by Fb and Fc (10% each).



P.G. Desmet

Figure 5.28 SKr 19 Aggeneys Gravel Vygieveld: A calcrete patch on the Farm Koeries (northwest of Aggeneys, northern Bushmanland). This patch is unusual in having a dense cover of both calcrete and quartzite pebbles. The dominant shrubby species is *Fagonia capensis* and the grass is *Stipagrostis obtusa*. A local endemic *Lithops julii* var. *julii* is restricted to this habitat.

Climate Seasonal winter rainfall (May to September). MAP about 160 mm, with epizodic drought periods (well below 100 mm per year) of one or two years in succession. Dew is present throughout the winter. MAT 16.6°C. Hot summers, with mean maximum and minimum daily temperatures 30°C and 5°C for January and July, respectively. Frost occurs about 8 days per year, but can vary widely from year to year. See also climate diagram for SKn 1 Namaqualand Klipkoppe Shrubland (Figure 5.29).

Important Taxa Succulent Tree: *Aloe dichotoma* var. *dichotoma* (d). Small Trees: *Ficus ilicina*, *Pappea capensis*. Succulent Shrubs: *Didelta spinosa* (d), *Euphorbia decussata* (d), *E. mauritanica* (d), *Leipoldtia schultzei* (d), *Adromischus marianiae* var. *immaculatus*, *Antimima*

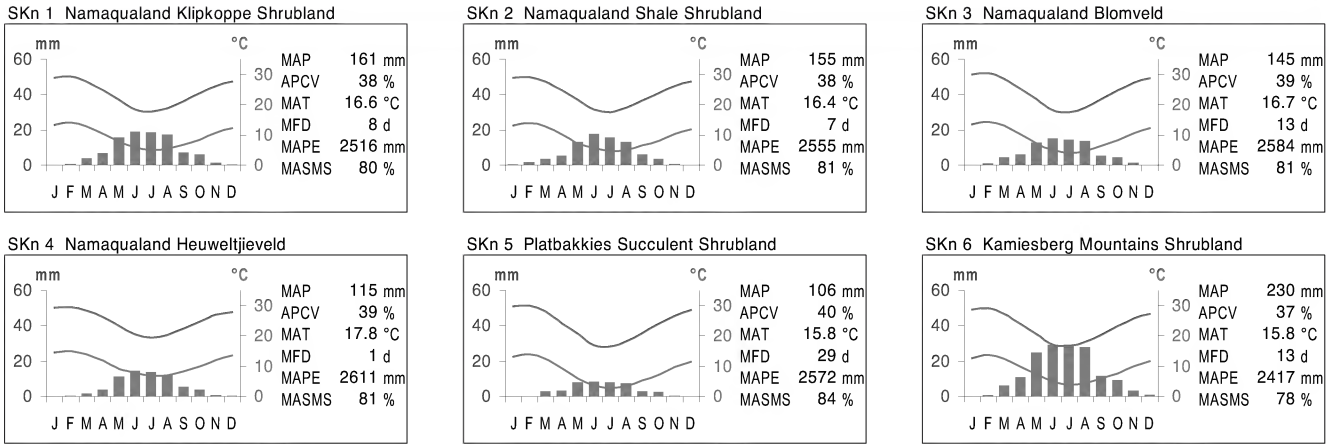
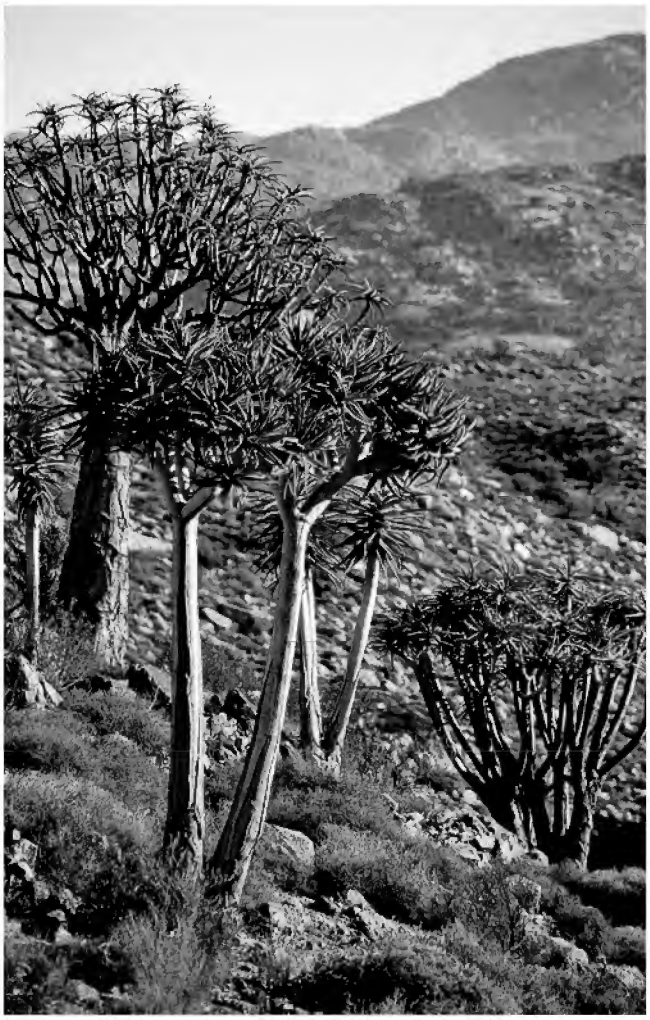


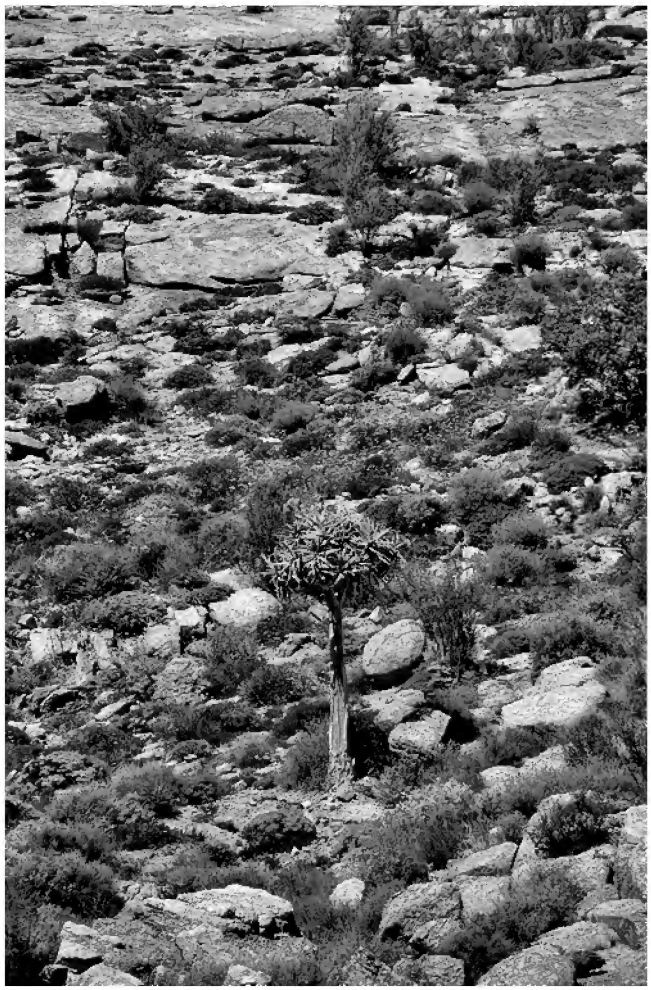
Figure 5.29 Climate diagrams of Namaqualand Hardeveld Bioregion units. Blue bars show the median monthly precipitation. The upper and lower red lines show the mean daily maximum and minimum temperature respectively. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days (days when screen temperature was below 0°C); MAPE: Mean Annual Potential Evaporation; MASMS: Mean Annual Soil Moisture Stress (% of days when evaporative demand was more than double the soil moisture supply).

mesklipensis, *Cotyledon cuneata*, *C. orbiculata* var. *orbiculata*, *Crassula atropurpurea* var. *watermeyeri*, *C. tetragona* subsp. *robusta*, *Manochlamys albicans*, *Othonna cylindrica*, *O. floribunda*, *O. furcata*, *Pelargonium crithmifolium*, *Phyllobolus roseus*, *Ruschia goodiae*, *R. viridifolia*, *Sarcocaulon crassicaule*, *S. l'heritieri*, *Senecio junceus*, *Stoeberia utilis*, *Tetragonia fruticosa*, *Tylecodon paniculatus*, *T. striatus*, *T. wallichii* subsp. *wallichii*, *Zygophyllum foetidum*, *Z. morgsana*. Tall Shrubs: *Dodonaea viscosa* var. *angustifolia*, *Euclea tomentosa*, *Montinia caryophyllacea*, *Putterlickia pyracantha*, *Rhus undulata*. Low Shrubs:



L. Mucina

Figure 5.30 SKn 1 Namaqualand Klipkoppe Shrubland: Kokerboom (*Aloe dichotoma* var. *dichotoma*) stand on granodiorite slopes in the Goegap Nature Reserve (Namaqualand, Northern Cape).



L. Mucina

Figure 5.31 SKn 1 Namaqualand Klipkoppe Shrubland: Rocky granodiorite slope with succulent shrubland (*Ruschia*, *Leipoldtia*, *Eriocephalus*, *Othonna*) and scattered populations of kokerboom (*Aloe dichotoma*) in the Goegap Nature Reserve (Namaqualand, Northern Cape).

Berkheya fruticosa (d), *Eriocephalus microphyllus* var. *pubescens* (d), *Galenia africana* (d), *Hermannia disermifolia* (d), *Lebeckia sericea* (d), *Acanthopsis spathularis*, *Antizoma miersiana*, *Asparagus capensis* var. *capensis*, *Athanasia flexuosa*, *Ballota africana*, *Berkheya ferox*, *Eriocephalus brevifolius*, *Galenia fruticosa*, *Gnidia meyeri*, *Helichrysum scabrum*, *H. tricostatum*, *Indigofera nigromontana*, *Maytenus oleoides*, *Passerina galpinii*, *Pelargonium grandicalcaratum*, *P. praemorsum*, *Pharnaceum albens*, *Phylica montana*, *P. oleaefolia*, *Pteronia divaricata*, *P. incana*, *Selago divaricata*, *S. glutinosa*, *Senecio cinerascens*, *Solanum burchellii*, *S. giftbergense*, *Tripteris oppositifolia*, *T. sinuata*. Semiparasitic Shrubs: *Thesium lineatum*, *T. patulum*, *T. polycephalum*, *T. spinosum*. Woody Succulent Climber: *Sarcostemma viminale*. Woody Climbers: *Asparagus retrofractus*, *Astephanus triflorus*, *Microloma sagittatum*. Herbaceous Climber: *Cysticapnos grandiflora*. Semiparasitic Epiphytic Shrub: *Viscum capense*. Herbs: *Tripteris amplectens* (d), *T. hyoseroides* (d), *Adenogramma glomerata*, *Aizoon canariense*, *Arctotis revoluta*, *Diascia diffusa*, *Felicia bergeriana*, *Galium tomentosum*, *Heliophila amplexicaulis*, *H. thunbergii*, *H. variabilis*, *Hemimeris racemosa*, *Hermannia althaeifolia*, *Oncosiphon suffruticosum*, *Plantago cafra*, *Senecio glabrifolius*, *Trichogyne paronychioides*, *Tripteris microcarpa*, *Ursinia cakilefolia*, *Wahlenbergia oxyphylla*. Geophytic Herbs: *Ornithogalum multifolium*, *O. rupestre*, *Oxalis ambigua*, *O. obtusa*, *O. pes-caprae*, *Trachyandra falcata*. Succulent Herbs: *Conophytum breve*, *C. depressum*, *Crassula muscosa*, *C. tomentosa*, *Tetragonia microptera*. Graminoids: *Ehrharta calycina* (d), *Chaetobromus involucratus* subsp. *dregeanus*, *Ehrharta barbinodis*, *E. delicatula*, *Fingerhuthia africana*, *Tribolium echinatum*.

Biogeographically Important Taxa ([NQ]Namaqualand endemic, [N]Northern distribution limit, [S]Southern distribution limit) Small Trees: *Ozoroa concolor*[NQ], *O. dispar*[NQ]. Succulent Shrubs: *Polymita albiflora*[NQ] (d), *Aloe striata* subsp. *komaggasensis*[NQ], *Cheiridopsis denticulata*[NQ], *Crassula brevifolia* subsp. *brevifolia*[NQ], *Euphorbia oxystegia*[NQ], *Othonna euphorbioides*[NQ], *Psilocaulon foliolosum*[NQ], *Stoeberia frutescens*[NQ], *Tylecodon similis*[NQ], *T. wallichii* subsp. *ecklonianus*[S]. Tall Shrub: *Otholobium striatum*[N]. Low Shrubs: *Acanthopsis horrida*[NQ], *Asparagus alopecurus*[NQ], *Athanasia linifolia*[N], *Chrysocoma oblongifolia*[N], *Dischisma clandestinum*[NQ], *Euryops brevipapposus*[N], *Felicia brevifolia*[S], *Oedera sedifolia*[N], *Pelargonium abrotanifolium*[N], *P. sericifolium*[NQ], *Pteronia leptospermoides*[NQ], *P. ovalifolia*[N], *Salvia dentata*[NQ], *S. lanceolata*[N], *Selago speciosa*[N], *Senecio parvifolius*[N]. Woody Succulent Climber: *Crassula rudolfii*[NQ]. Woody Climbers: *Asparagus multituberosus*[N], *Indigofera amoena*[N], *Microloma calycinum*[NQ]. Herbaceous Succulent Climber: *Crassula roggeveldii*[N]. Herbs: *Adenogramma mollugo*[N], *Annesorhiza nuda*[N], *Gorteria diffusa* subsp. *calendulacea*[NQ], *Hermannia stipitata*[NQ], *Jamesbrittenia pedunculosa*[NQ], *Manulea altissima* subsp. *glabricaulis*[NQ], *Mollugo namaquensis*[NQ], *Phyllopodium anomalum*[N], *Polycarena capensis*[N], *Sonderina tenuis*[N], *Wahlenbergia cernua*[N]. Geophytic Herbs: *Babiana curviscapa*[NQ], *B. dregei*[NQ], *B. stenomera*[NQ], *Gladiolus equitans*[NQ], *Lapeirousia pyramidalis*[N], *L. silenoides*[NQ], *Oxalis comosa*[NQ], *O. furcillata* var. *furcillata*[NQ], *O. namaquana*[NQ], *Pelargonium bubonifolium*[NQ], *Romulea citrina*[NQ], *R. namaquensis*[NQ], *Tenicroa multifolia*[NQ], *Trachyandra involucrata*[NQ], *Whiteheadia bifolia*[NQ]. Succulent Herbs: *Cleretum papulosum* subsp. *schlechteri*[NQ], *Conophytum bilobum*[NQ], *Crassula dichotoma*[N], *C. hirsuta*[NQ], *Othonna macrophylla*[NQ], *Quaqua cincta*[NQ]. Graminoids: *Aristida dasydesmis*[NQ], *Ehrharta erecta*[N], *Pentaschistis patula*[N].

Endemic Taxa Succulent Shrubs: *Ottosonderia monticola*, *Tylecodon nigricaulis*. Low Shrubs: *Lotononis benthamiana*, *L. longiflora*, *L. quinata*, *Wiborgia incurvata*. Herbs: *Tripteris spathulata*, *Zaluzianskya collina*. Geophytic Herbs: *Ornithogalum leeupoortense*, *Oxalis clavifolia*, *O. louisae*, *Xysmalobium pearsonii*. Succulent Herbs: *Quaqua bayeriana*, *Q. pallens*, *Stapeliopsis khamiesbergensis*.

Conservation Least threatened. Some 6% statutorily conserved in Namaqua National Park (incl. former WWF Skilpad Wild Flower Reserve), Goegab Nature Reserve with spectacular granite-koppie landscapes, and a small portion in the Moedverloren Nature Reserve. Target 28%. Largely without any alien invaders and hardly any transformation due to agriculture (steep rocky habitats), but old mine spoils (mainly copper) are a disturbing view in some localities. Erosion is moderate (35%), very low (35%) or low (30%).

Remark Spring flower displays, beautiful rock formations and a wealth of succulents make this a very popular tourist area, both nationally and internationally. One of the local botanical celebrities is the famous kokerboom (*Aloe dichotoma*). Historically these trees were also found on the flats between the rocky hills, but they were heavily utilised by the local inhabitants for making coolers to keep food fresh and also for building houses. In Namaqualand, *Tylecodon paniculatus* is found only on steep, south-facing slopes, while in the moister Succulent Karoo further south (e.g. in Robertson Karoo) this species is usually found on north-facing slopes or on heuweltjies.

References Le Roux (1984), Rösch (2001), L. Mucina (unpublished data).

SKn 2 Namaqualand Shale Shrubland

VT 33 Namaqualand Broken Veld (79%) (Acocks 1953). LR 56 Upland Succulent Karoo (55%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Area some 10 km to the north and to the southwest of Steinkopf in southeastern Richtersveld. Reaching as far south as Spektakelberg west of Springbok. Most of the area situated at altitudes between 500–1 100 m.

Vegetation & Landscape Features Smooth hilly country supporting mostly dense shrubland (due to high local rainfall and mild temperatures), often with strong abundance of *Galenia africana* and *Eriocephalus* spp. and locally dominant *Elytropappus rhinocerotis*. Rocky habitats support abundant dwarf succulents.

Geology & Soils Shales of Schwarzrand Subgroup accompanied by quartzites of the Kuibis Subgroup and of the Cambrian Nama Group supporting shallow soils over quartzite and deep-profile soils over shales. Almost 90% of the area falls within Fb land type, while the rest is largely classified as Ib land type.

Climate Seasonal, frontal winter rainfall peaking between May and August. Occasional late summer thunderstorms occur between February and April. MAP ranges from about 120 mm at low elevations to about 200 mm at higher elevations (overall MAP 155 mm). It is possible that areas along the edge of the escarpment such as Naries and Nigramoep would receive as much as 350 mm due to a regional precipitation effect. Mean maximum and minimum monthly temperatures in Nigramoep are 32°C and –5°C for February and July, respectively. The overall MAT lies between 16°C and 17°C. Incidence of frost averages 10 days per year, ranging from fewer than 5 days to more than 30 days per year. See also climate diagram for SKn 2 Namaqualand Shale Shrubland (Figure 5.29).

Important Taxa Succulent Shrubs: *Euphorbia mauritanica* (d), *Cheiridopsis namaquensis*, *Crassula tetragona* subsp. *robusta*, *Didelta spinosa*, *Lampranthus otzenianus*, *L. watermeyeri*, *Manochlamys albicans*, *Monilaria obconica*, *Pelargonium*

L. Mucina

Figure 5.32 SKn 2 Namaqualand Shale Shrubland: Undulating landscape built of Nama shales and supporting endemic-rich succulent shrubland in northern Namaqualand (Spektakelberg, west of Springbok).

crithmifolium, *P. echinatum*, *P. karooicum*, *Ruschia extensa*, *Tetragonia glauca*, *Tylecodon paniculatus*, *T. wallichii* subsp. *wallichii*, *Zygophyllum foetidum*. Tall Shrubs: *Dodonaea viscosa* var. *angustifolia* (d), *Rhus populifolia*. Low Shrubs: *Elytropappus rhinocerotis* (d), *Asparagus capensis* var. *capensis*, *Athanasia flexuosa*, *Berkheya fruticosa*, *Blepharis mitrata*, *Chrysocoma longifolia*, *Eriocephalus brevifolius*, *E. microphyllus* var. *pubescens*, *Euryops dregeanus*, *Galenia africana*, *Gnidia meyeri*, *Helichrysum hebelepis*, *H. oxybelium*, *H. tricostatum*, *Indigofera nigromontana*, *Lebeckia sericea*, *Phylica oleaefolia*, *Pteronia glabrata*, *P. incana*, *Selago glutinosa*, *Wahlenbergia tenella*, *Zygophyllum spinosum*. Semiparasitic Shrubs: *Thesium namaquense*, *T. patulum*, *T. polycephalum*. Woody Climbers: *Asparagus fasciculatus*, *A. multituberosus*, *Astephanus triflorus*, *Microloma sagittatum*. Herbaceous Succulent Climber: *Crassula roggeveldii*. Herbaceous Climbers: *Convolvulus capensis*, *Cysticapnos grandiflora*. Herbs: *Aizoon canariense* (d), *Cotula laxa* (d), *Heliophila crithmifolia* (d), *Leysera tenella* (d), *Plantago cafra* (d), *Diascia diffusa*, *Felicia bergeriana*, *F. tenella* subsp. *longifolia*, *Helichrysum leontonyx*, *Heliophila amplexicaulis*, *H. thunbergii*, *Hemimeris racemosa*, *Polygala refracta*, *Senecio glabrifolius*, *S. glutinarius*, *Silene burchellii* var. *angustifolia*, *Tripteris microcarpa*, *Ursinia anthemoides* subsp. *anthemoides*, *U. anthemoides* subsp. *versicolor*, *U. nana*, *U. speciosa*. Geophytic Herbs: *Bulbine disimilis*, *B. sedifolia*, *Bulbinella gracilis*, *Cheilanthes hirta*, *Chlorophytum undulatum*, *Drimia intricata*, *Hesperantha bachmannii*, *Lachenalia undulata*, *Melasphaerula ramosa*, *Moraea miniata*, *Ornithogalum hispidum*, *O. rupestre*, *Oxalis obtusa*, *O. purpurea*, *Spiloxene scullyi*, *Xenoscapa fistulosa*. Succulent Herbs: *Crassula tenuipedicellata*, *C. tomentosa*, *Tetragonia microptera*. Graminoids: *Cynodon dactylon* (d), *Ehrharta calycina*, *E. delicatula*, *E. longiflora*, *Merxmuellera stricta*.

Biogeographically Important Taxa ([NQ]Namaqualand endemic, [N]Northern distribution limit) Succulent Shrubs: *Adromischus phillipsiae*[N], *Antimima dasyphylla*[N], *Cheiridopsis denticulata*[NQ], *C. meyeri*[NQ], *C. rostrata*[N], *Euphorbia oxystegia*[NQ], *Othonna pteronioides*[N]. Tall Shrubs: *Cliffortia amplexistipula*[N], *C. ruscifolia* var. *purpurea*[N]. Low Shrubs: *Agathosma serpyllacea*[N], *Aspalathus cymbiformis*[N], *A. hispida* subsp. *albiflora*[N], *Asparagus alopecurus*[NQ], *Diosma ramosissima*[N], *Dischisma clandestinum*[NQ], *Eriocephalus macroglossus*[NQ], *Euryops namaquensis*[N], *Lobostemon glaucophyllus*[N], *Lotononis densa* subsp. *gracilis*[N], *Microdon polygaloides*[N], *Oedera genistifolia*[N], *Oftia revoluta*[NQ], *Otholobium hirtum*[N], *Passerina galpinii*[N], *Pelargonium sericifolium*[NQ], *Pharnaceum incanum*[N], *Pteronia leptospermoides*[NQ], *Selago acocksii*[N], *S. triquetra*[N], *Stachys flavescens*[NQ], *Struthiola leptantha*[N], *Tetragonia namaquensis*[NQ], *Wiborgia fusca* subsp. *fusca*[N]. Woody Succulent Climber: *Crassula rudolfii*[NQ]. Woody Climbers: *Asparagus aethiopicus*[N], *Microloma namaquense*[NQ]. Herbs: *Annesorhiza altiscapa*[N], *Chamarea capensis*[N], *Cotula bipinnata*[N], *Dimorphotheca acutifolia*[N], *Gorteria diffusa* subsp. *calendulacea*[NQ], *Heliophila gariepina*[NQ], *H. laciniata*[NQ], *Hermannia althaeifolia*[N], *Manulea cheiranthus*[N], *Osteospermum acanthospermum*[N], *Polycarena pubescens*[N], *Wahlenbergia acaulis*[N]. Geophytic Herbs: *Androcymbium dregei*[N], *A. scabromarginatum*[NQ], *A. volutare*[N], *Babiana curviscapa*[NQ], *B. stenomera*[NQ], *Bulbinella divaginata*[N], *Empodium plicatum*[N], *Geissorhiza namaquensis*[NQ], *Gladiolus arcuatus*[NQ], *Haemanthus unifoliatus*[NQ], *Holothrix aspera*[N], *H. filicornis*[NQ], *Lachenalia carnosa*[NQ], *L. unifolia* var. *schlechteri*[N], *Moraea galaxia*[N], *M. herrei*[NQ], *M. unguiculata*[N], *Ornithogalum concordianum*[N], *O. geniculatum*[NQ], *O. pruinosum*[NQ], *Oxalis dregei*[N], *O. eckloniana* var. *hopefieldiana*[N], *O. furcillata* var. *furcillata*[NQ], *O. grammopetala*[N], *O. melanosticta* var. *melanosticta*[N], *O. namaquana*[NQ], *Pelargonium bubonifolium*[NQ], *P. incrassatum*[NQ], *Romulea citrina*[NQ], *R. namaquensis*[NQ], *Satyrium erectum*[N], *Trachyandra involucrata*[NQ]. Succulent Herbs: *Aloe melanacantha*[NQ], *Conophytum bilobum*[NQ], *Crassula capensis* var. *capensis*[N], *C. glomerata*[N], *Othonna incisa*[NQ], *O. macrophylla*[NQ], *O. obtusiloba*[NQ], *O. retrorsa*[NQ], *Phyllobolus oculatus*[NQ]. Graminoids: *Ficinia argyropa*[N], *F. deusta*[N], *Tribolium echinatum*[N], *T. hispidum*[N].

Endemic Taxa Succulent Shrubs: *Cheiridopsis aspera*, *C. delphinoides*, *C. peculiaris*, *C. umdausensis*, *Odontophorus marlothii*, *Tylecodon atropurpureus*, *T. hirtifolius*, *T. tribblei*, *T. tuberosus*. Low Shrub: *Phylica pearsonii*. Geophytic Herbs: *Lachenalia namaquensis*, *Lapeirousia verecunda*, *Moraea margaretae*, *M. namaquana*, *Pelargonium aridicola*, *Strumaria merxmuelleriana*. Succulent Herb: *Brownanthus lignescens*.

Conservation Least threatened and none conserved in statutory conservation areas. Some protection is warranted on private game farms. Target 24%. Only very small part transformed, but this might change due to overall better suited deep-soil habitats found within the area. No obvious invasions of alien plants. Erosion is mostly moderate.

Remark 1 Namaqualand Shale Shrubland is phytogeographically one of the most intriguing vegetation units. It is supported by a peculiar combination of high altitude experiencing slightly higher local rainfall as well as occasional mist and of substrate—Nama shales weathering into clay-rich, heavy soils able to retain water in a more efficient way than the dominant granite-derived sandy soils of northern and central Namaqualand. These unique pedo-hydrological (and geological) conditions create habitat islands supporting a number of apparently relictual (Midgley et al. 2001) Cape elements of the genera *Aspalathus, Cliffortia, Diosma, Elytropappus, Gladiolus, Holothrix, Metalasia,*

Moraea, Oedera, Oxalis, Romulea, Satyrium and *Phylica*—represented by taxa reaching their northern distribution limits here. A number of taxa, such as *Cliffortia ruscifolia* var. *purpurea*, occurring all the way along the high altitudes of South African meseta (along the Escarpment) from as far as Limpopo Province and Mpumalanga also reach their northwestern limits of distribution here. The local endemism, counting 26 taxa so far (some still pending formal description) is also remarkable.

Remark 2 Low & Rebelo (1996) mapped a small portion of this unit (Spektakelberg area) as part of North-western Mountain Renosterveld. There are indeed some patches of vegetation reminiscent of shrubby renosterveld (with *Elytropappus rhinocerotis* dominant—see for example Van Jaarsveld & Koutnik 2004: 54, Figure 59) on the Farm Eselsfontein. Future research will possibly bring more clarity on the extent and identity of these patches and the renosterveld on the escarpment west of Springbok can become recognised again.

Reference P.G. Desmet (unpublished data).

SKn 3 Namaqualand Blomveld

VT 33 Namaqualand Broken Veld (61%) (Acocks 1953). LR 56 Upland Succulent Karoo (62%) (Low & Rebelo 1996).

Distribution Northern Cape Province and to a small extent also Western Cape Province: Valleys and flat areas (piedmonts, vlaktes) between granitic rocky hills of the Namaqualand Escarpment, from Steinkopf southwards to Bitterfontein. Most of the area at altitudes 460–1 080 m.

Vegetation & Landscape Features Level to slightly undulating sedimentary surfaces between rocky granitic hills and mountains, such as wide plains and broad valleys with dry channels of intermittent water courses. Sparse dwarf shrubs with succulent or ericoid leaves dominate these shrublands. Geophytes and ephemeral herbs and in places also low, spreading, leaf-succulents show spectacular flower displays (hence the name of the unit) in wet years.

Geology & Soils Underlain by granite-gneisses and metasediments of Mokolian age, affected by the Namaqualand Metamorphic Event. Supporting relatively deep, yellow-brown, fine to coarse loamy sand derived through weathering of the granite rocks. Ag and Ae land types make up almost 80% of the area, followed by Fc land type accounting for a further 15%.

Climate Seasonal winter rainfall (May to September) with sporadic drought periods (well below 100 mm per year) of one or two years in succession. Dew is present throughout the winter. MAP 145 mm. An average of 13 days of frost per year, but varying greatly from year to year. Mean maximum and minimum daily temperatures from January to February and June to August span 29–32°C and 3–5°C, respectively. See also climate diagram for SKn 3 Namaqualand Blomveld (Figure 5.29).

Important Taxa Succulent Shrubs: *Drosanthemum hispidum* (d), *Euphorbia mauritanica* (d), *Galenia sarcophylla* (d), *Hypertelis salsoloides* (d), *Leipoldtia schultzei* (d), *Ruschia robusta* (d), *Aridaria noctiflora* subsp. *noctiflora*, *Euphorbia decussata*, *Lycium cinereum*, *Ruschia brevibracteata*, *Tetragonia fruticosa*, *T. robusta* var. *psiloptera*, *Tylecodon wallichii* subsp. *wallichii*. Low Shrubs: *Eriocephalus microphyllus* var. *pubescens* (d), *Galenia africana* (d), *Aptosimum indivisum*, *A. spinescens*, *Asparagus capensis* var. *capensis*, *Berkheya fruticosa*, *Hermannia disermifolia*, *H. trifurca*, *Peliostomum virgatum*, *Pentzia incana*, *Pteronia divaricata*, *Tripteris sinuata*, *Zygophyllum retrofractum*. Semiparasitic Shrub: *Thesium lineatum*. Woody Climbers: *Astephanus triflorus*, *Microloma sagittatum*. Herbaceous Climber: *Cysticapnos grandiflora*. Herbs: *Aizoon canariense* (d), *Arctotheca calendula* (d), *Arctotis fastuosa* (d), *Dimorphotheca sinuata* (d), *Felicia merxmuelleri* (d), *Foveolina dichotoma* (d), *Gazania lichtensteinii* (d), *Gorteria diffusa* subsp. *diffusa* (d), *Grielum humifusum* (d), *Heliophila coronopifolia* (d), *H. variabilis* (d), *Leysera gnaphalodes* (d), *L. tenella* (d), *Oncosiphon grandiflorum* (d), *O. suffruticosum* (d), *Plantago cafra* (d), *Senecio arenarius* (d), *S. cardaminifolius* (d), *Ursinia cakilefolia* (d), *U. nana*, *Adenogramma glomerata*, *Felicia bergeriana*, *F. namaquana*, *F. tenella* subsp. *cotuloides*, *Gazania leiopoda*, *Heliophila seselifolia* var. *nigellifolia*, *Hermannia althaeifolia*, *Jamesbrittenia racemosa*, *Lessertia diffusa*, *Lotononis falcata*, *Nemesia affinis*, *Pelargonium redactum*, *Trichogyne paronychioides*, *Zaluzianskya benthamiana*. Geophytic Herbs: *Massonia depressa* (d), *Oxalis obtusa* (d), *Eriospermum paradoxum*, *Hesperantha pauciflora*, *Lachenalia violacea*, *Moraea serpentina*, *Ornithogalum hispidum*, *Oxalis inconspicua*, *Pelargonium triste*, *Tulbaghia dregeana*. Succulent Herbs: *Crassula thunbergiana* (d), *Conicosia elongata*, *Crassula muscosa*, *Tetragonia microptera*. Graminoids: *Karroochloa schismoides* (d), *Chaetobromus involucratus* subsp. *dregeanus*, *Ehrharta barbinodis*, *E. calycina*, *E. longiflora*, *Schismus barbatus*.

Biogeographically Important Taxa ([NQ]Namaqualand endemic, [N]Northern distribution limit) Succulent Shrubs: *Cheiridopsis denticulata*[NQ], *Othonna abrotanifolia*[NQ], *Prenia pallens* subsp. *namaquensis*[NQ]. Low Shrubs: *Dischisma clandestinum*[NQ], *Indigofera dillwynioides*[N], *Salvia dentata*[NQ]. Herbaceous

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Figure 5.33 SKn 3 Namaqualand Blomveld: Spring display of vygies (*Ruschia* species, pink) and Asteraceae including *Arctotis fastuosa* (deep orange), *Foveolina dichotoma* (small yellow-flowered plant in the foreground) and *Tripteris sinuata* (yellow-flowered shrubs in the background) in the Goegap Nature Reserve (Springbok, Northern Cape).

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Figure 5.34 SKn 3 Namaqualand Blomveld: Spring flower display of *Heliophila seselifolia* (white), *Senecio cardaminifolius* (yellow) and *Arctotis fastuosa* (orange) in an old field in the Goegap Nature Reserve near Springbok (Namaqualand, Northern Cape).

the only perennial species sometimes is *Galenia africana*. In lightly grazed areas many of the palatable perennial species can also be present. In disturbed areas on the eastern side of the Namaqualand Escarpment, this unit can be dominated by *Ruschia robusta.*

Remark 2 The sandy flats among the granite and granodiorite koppies of Namaqualand have been the subject of intensive research into population and vegetation dynamics, especially including aspects such as annual phenology of the short-lived plant communities, competitive relations and seed ecology (Van Rooyen et al. 1979a, b, Van Rooyen & Grobbelaar 1982, Le Roux 1984, Theron et al. 1993, Steyn et al. 1996, Van Rooyen et al. 1996, Rösch et al. 1997a, b, c; see also Van Rheede van Oudtshoorn & Van Rooyen 1999 for further references).

References Van Rooyen et al. (1979a, b, 1996), Van Rooyen & Grobbelaar (1982), Le Roux (1984), Theron et al. (1993), Steyn et al. (1996), Rösch et al. (1997a, b, c).

Climber: *Cyphia angustifolia*[N]. Herbs: *Hebenstretia hamulosa*[NQ], *Heliophila laciniata*[NQ], *Jamesbrittenia pedunculosa*[NQ], *Lotononis rostrata* subsp. *namaquensis*[NQ], *L. stenophylla*[N], *Manulea decipiens*[NQ], *Mollugo namaquensis*[NQ], *Monopsis debilis* var. *gracilis*[NQ], *Polycarena rariflora*[N], *Wahlenbergia prostrata*[NQ]. Geophytic Herbs: *Babiana curviscapa*[NQ], *B. dregei*[NQ], *Gladiolus arcuatus*[NQ], *Lachenalia carnosa*[NQ], *L. hirta*[N], *Lapeirousia silenoides*[NQ], *Moraea collina*[N], *Pelargonium incrassatum*[NQ], *Romulea citrina*[NQ], *Wurmbea capensis*[N].

Endemic Taxa Herbs: *Lessertia capitata*, *Lotononis arenicola*. Succulent Herbs: *Dorotheanthus bellidiformis* subsp. *hestermalensis*, *D. rourkei*.

Conservation Target 28%. Small areas (1.5%) statutorily conserved in Goegab Nature Reserve and Namaqua National Park. Some protection is warranted on private game farms. Only about 6% of the total area is transformed, mainly by grain cultivation and some planting of salt-bush (*Atriplex nummularia*). Overgrazing is found almost throughout this unit. The most serious invasive plants are American *Amsinckia retrorsa*, Eurasian *Erodium* and *Bromus*, and Australian *Atriplex lindleyi* subsp. *inflata*. All alien infestations are only of local extent. Erosion is low (40%), very low (30%) or moderate (30%).

Remark 1 The vegetation on abandoned (formerly ploughed) fields is the result of continued disturbance, first by ploughing and then the vegetation is kept from recovery by heavy grazing of the annuals and palatable perennial seedlings. In areas with loamy soils *Drosanthemum hispidum*, *Galenia sarcophylla* and *Hypertelis salsoloides* are sometimes dominant, while elsewhere

SKn 4 Namaqualand Heuweltjieveld

VT 31 Succulent Karoo (88%) (Acocks 1953). LR 57 Lowland Succulent Karoo (79%) (Low & Rebelo 1996).

Distribution Northern Cape Province: At the western foothills of the Namaqualand Escarpment from west of Steinkopf southwards to Soebatsfontein and to Kotzesrust. Altitude ranging from 100–540 m (most of the area).

Vegetation & Landscape Features Undulating plains leading up to the Escarpment with a mosaic of communities on heuweltjies (slightly raised, rounded termite mounds up to 10

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Figure 5.35 SKn 4 Namaqualand Heuweltjieveld: Undulating granite landscape south of Garies dotted by numerous heuweltjies with *Drosanthemum hispidum* (Aizoaceae) and *Arctotis fastuosa* (Asteraceae) dominant.

m in diameter) and in between the heuweltjies. Low shrubland (canopy cover 20–45%) dominated by leaf-succulent shrubs.

Geology & Soils Deep red loamy soils on granites and gneisses of Mokolian age (most significantly the Kamieskroon Gneiss and Gladkop Suite). Ag land type dominates the area (58%), while Ae land type makes up most of the remainder of the area.

Climate Winter-rainfall climate with irregular rain events occurring mostly from May to August and almost always no rain between November and February. MAP of 115 mm. Dew is experienced throughout the winter. MAT is quite high (17.8°C) and frosts hardly occur. In the coldest months of the year (May to August) temperatures below 10°C are often recorded. The highest temperatures are reached from December to January (may well exceed 30°C). See also climate diagram for SKn 4 Namaqualand Heuweltjieveld (Figure 5.29).

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Figure 5.36 SKn 4 Namaqualand Heuweltjieveld: Ancient termitaria (heuweltjies) east of Wallekraal in Namaqualand (Northern Cape).

Important Taxa Succulent Shrubs: *Drosanthemum hispidum* (d), *Euphorbia ephedroides* var. *ephedroides* (d), *Jordaaniella cuprea* (d), *Lampranthus otzenianus* (d), *Ruschia leucosperma* (d), *R. robusta* (d), *Salsola namibica* (d), *Antimima compacta*, *Aridaria noctiflora* subsp. *noctiflora*, *Didelta carnosa* var. *carnosa*, *Eberlanzia parvibracteata*, *Lycium cinereum*, *Manochlamys albicans*, *Salsola aellenii*, *S. aphylla*, *Sarcocaulon flavescens*, *Tetragonia fruticosa*, *T. spicata*. Low Shrubs: *Galenia fruticosa* (d), *Lebeckia halenbergensis* (d), *Anthospermum aethiopicum*, *Berkheya fruticosa*, *Galenia africana*, *Hermannia trifurca*, *Hirpicium alienatum*, *Limeum africanum*, *Pelargonium praemorsum*, *Pentzia globosa*, *Pteronia glabrata*, *Tripteris oppositifolia*, *Zygophyllum retrofractum*. Herbs: *Arctotis fastuosa* (d), *Dimorphotheca sinuata* (d), *Leysera tenella* (d), *Oncosiphon suffruticosum* (d), *Osteospermum pinnatum* (d), *Tripteris microcarpa* (d), *Amellus microglossus*, *A. strigosus* subsp. *pseudoscabridus*, *Emex australis*, *Felicia bergeriana*, *F. tenella* subsp. *longifolia*, *Pharnaceum croceum*, *Plantago cafra*, *Rhynchopsidium pumilum*, *Ursinia cakilefolia*, *Zaluzianskya villosa*. Geophytic Herb: *Oxalis annae* (d). Succulent Herbs: *Mesembryanthemum guerichianum* (d), *Psilocaulon junceum* (d), *Tetragonia microptera* (d). Graminoids: *Ehrharta calycina* (d), *E. longiflora* (d), *E. pusilla*, *Pentaschistis airoides*, *Tribolium echinatum*, *T. utriculosum*.

Biogeographically Important Taxa (all Namaqualand endemics) Succulent Shrubs: *Psilocaulon foliosum* (d), *Stoeberia frutescens* (d). Low Shrub: *Tetragonia namaquensis*.

Conservation Not under immediate threat except for local intensive grazing pressure responsible for veld degradation. Target 28%. Some 11% of the area of the unit statutorily conserved in Namaqua National Park. Scattered *Acacia cyclops* can be seen as an infestation problem on about 5% of the area in this unit. About 3–4% of the area is transformed by cultivation. Erosion remains at very low to low levels.

Remark Heuweltjies are often dominated by *Lampranthus otzenianum* and *Psilocaulon foliosum*. In other places the heuweltjies are turned into bare circles by overgrazing, often with *Oncosiphon suffruticosum* as the only species occurring here. The heuweltjies are often the home of burrowing animals like erdvark or antbear (*Orycteropus afer*), porcupine (*Hystrix africaeaustralis*) and Brants' whistling rat (*Parotomys brantsii*). Species turnover is considerable within this vegetation unit due to its large north-south extent. Some of the patches are floristically related to the SKr 13 Southern Richtersveld Scorpionstailveld.

SKn 5 Platbakkies Succulent Shrubland

VT 33 Namaqualand Broken Veld (61%) (Acocks 1953). LR 49 Bushmanland Nama Karoo (56%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Western piedmonts at boundaries between Namaqualand Hardeveld and Bushmanland between Gamoep in the north and Banke in the south. Altitude 820–1 140 m (most of the area 920–1 120 m).

Vegetation & Landscape Features Mainly plains, but also low koppies and hills dominated by shrubland vegetation (especially on koppies), low succulent shrub-dominated (e.g. *Ruschia robusta*) vegetation on loamy colluvial and rocky soil, and grass-dominated (e.g. *Stipagrostis brevifolia*) vegetation on sandy soil accumulations in valleys. Within this matrix are gravel plains of various types supporting vegetation characterised by the dominance of dwarf leaf-succulents (Aizoaceae and Crassulaceae) generally restricted to these types of habitats. The shrub component of the vegetation is phenologically adjusted to a winter-rainfall growth pattern, but the C_4 grass component of the vegetation responds well to the late summer-rainfall events.

Geology & Soils Gneiss of the Little Namaqualand Suite, and Bushmanland Group metasediments and metavolcanics with shallow unstructured soils predominate in the west. In the east the landscape is covered by sandy Bushmanland soils overlying calcrete. A unique feature in this vegetation type is the presence of silcrete caps (Bitterfontein Formation) along the edge of the erosion front between the Bushmanland surface and the underlying metamorphic rocks—these are associated with deeply weathered underlying gneiss giving rise to quartz pebble-covered gravel plains. In the east and north, another type of gravel plain is formed by the presence of palaeo-river terraces characterised by the presence of rounded rocks and

boulders and calcrete nodules. Northwest and west of Gamoep, and in the south around Banke, the gravel plains comprise quartz pebble lags over kaolinised gneiss, often associated with eroding silcrete outcrops. The dominant land type is Ag (78%), while the rest of the area is classified as Ae land type.

Climate Seasonal winter-rainfall climate with shallow peak from May to August. About a third of the annual rainfall (MAP slightly above 100 mm, range 80–120 mm) arrives as late summer thunderstorms. Overall MAT is about 16°C, mean maximum and minimum monthly temperatures in Platbakkies are 37°C and –3°C for January and July, respectively. Incidence of frost is between 20 and 40 days per year. See also climate diagram for SKn 5 Platbakkies Succulent Shrubland (Figure 5.29).

Important Taxon ([G]Gravel patches) Succulent Shrubs: *Aloinopsis luckhoffii*[G], *Euphorbia gentilis* subsp. *gentilis*[G], *Ihlenfeldtia excavata*[G], *Ruschia divaricata*, *Tylecodon reticulatus*[G]. Low Shrub: *Wahlenbergia oxyphylla*. Geophytic Herb: *Ornithogalum gethylloides*. Succulent Herbs: *Brownanthus vaginatus*, *Conophytum pellucidum* subsp. *cupreatum*[G], *Crassula columnaris* subsp. *prolifera*[G], *Lithops villetii* subsp. *villetii*[G].

Biogeographically Important Taxon (Namaqualand endemic) Succulent Shrub: *Cheiridopsis meyeri*.

Endemic Taxa ([G]Gravel patches) Succulent Shrub: *Vanheerdea primosii*[G]. Low Shrub: *Nenax namaquensis*. Succulent Herbs: *Conophytum arturolfago*[G], *C. caroli*, *C. jarmilae*, *C. pubicalyx*[G], *C. reconditum* subsp. *reconditum*, *C. tomasi*, *Lithops naureeniae*.

Conservation Target 28%. Overgrazing on communal land is a serious threat to this vegetation of which none is conserved in statutory conservation areas so far. Scattered alien *Prosopis* (on about 2–3% of the area) might also be seen as a conservation challenge. Erosion is low (70%) and very low (30%).

Remark The matrix vegetation on rocky and colluvial substrates reminds one of the SKn 1 Namaqualand Klipkoppe Shrubland, and that on sandy substrates is similar to NKb 3 Bushmanland Arid Grassland. The unique component of the vegetation occurs in special habitats comprising the quartz, palaeo-river terrace or gneiss grit-pan gravel patches and silcrete outcrops. The vegetation of these edaphically arid habitats is structurally typical of such habitats in the Succulent Karoo being dominated by low succulent plants. The recent discovery of several new species of *Conophytum* in this area indicates that there is still much to be discovered here. The delimitation of this vegetation type is primarily to draw attention to the presence of the gravel patches. These are generally too small and scattered throughout the landscape to map as a single discrete vegetation unit.

References Petersen (2003), P.G. Desmet (unpublished data).

SKn 6 Kamiesberg Mountains Shrubland

VT 33 Namaqualand Broken Veld (39%), VT 43 Mountain Renosterbosveld (29%) (Acocks 1953). LR 56 Upland Succulent Karoo (36%), LR 59 North-western Mountain Renosterveld (29%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Kamiesberg Mountains (central Namaqualand) from about 30 km north of Kamieskroon southwards almost to Kliprand as well as on western slopes of the northern Bokkeveld Escarpment in the Vanrhynsdorp-Nieuwoudtville area. Most of the area at altitudes of 800–1 160 m.

Vegetation & Landscape Features Steep, mainly south- to east-facing upper (high-altitude) slopes of large granite domes exposed to increased topographic precipitation as well as in deep gullies in the Hardeveld, supporting tall shrubland (canopy cover 45–65%) dominated by a mixture of nonsucculent (*Eriocephalus, Euclea, Euryops, Dodonaea, Hermannia, Lebeckia, Melianthus, Pteronia, Rhus, Salvia, Wiborgia*) and succulent (*Didelta, Euphorbia, Othonna, Ruschia, Tylecodon, Zygophyllum*) shrubs.

Geology & Soils Bitterfontein quartzites of the Bushmanland Group and the Kamieskroon gneiss occur in the north, giving rise to moderate to steep rocky slopes. Rock sizes vary from medium to large, with flat to gentle rock sheets as well as rock domes. In the south, the clastic sediments of the Knersvlakte Subgroup of the Vanrhynsdorp Group predominate. Most of the soils are yellow-brown to brown, loamy and sandy. Ib land type dominates the area (70%), while the rest is characterised by Ic land type.

Climate Winter-rainfall area with MAP of 230 mm. Almost all the rainfall occurs from May to August, while rain is very rare between December and February. Dew is experienced throughout the winter. Frost occurs for about 13 days of the year and the lowest temperatures in the winter are 5–10°C. The highest temperatures in summer are around 30°C. See also climate diagram for SKn 6 Kamiesberg Mountains Shrubland (Figure 5.29).

Important Taxa Small Tree: *Ficus cordata*. Tall Shrubs: *Dodonaea viscosa* var. *angustifolia* (d), *Euclea tomentosa* (d), *Montinia caryophyllacea* (d), *Olea europaea* subsp. *africana* (d), *Rhus undulata* (d), *Anisodontea triloba*, *Erythrophysa alata*, *Nylandtia spinosa*, *Rhus incisa*. Succulent Shrubs: *Didelta spinosa* (d), *Tylecodon paniculatus* (d), *Crassula dejecta*, *Euphorbia decussata*, *Leipoldtia schultzei*, *Othonna cylindrica*, *O. furcata*, *Ruschia multiflora*, *R. viridifolia*, *Senecio junceus*, *Tetragonia fruticosa*, *Zygophyllum foetidum*, *Z. morgsana*. Low Shrubs: *Berkheya fruticosa* (d), *Lebeckia sericea* (d), *Anthospermum*

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Figure 5.37 SKn 6 Kamiesberg Mountains Shrubland: *Didelta spinosa*-dominated shrubland with *Ursinia cakilefolia* fields in the background in the former Skilpad Flower Reserve, today part of the Namaqua National Park (near Kamieskroon, Northern Cape).

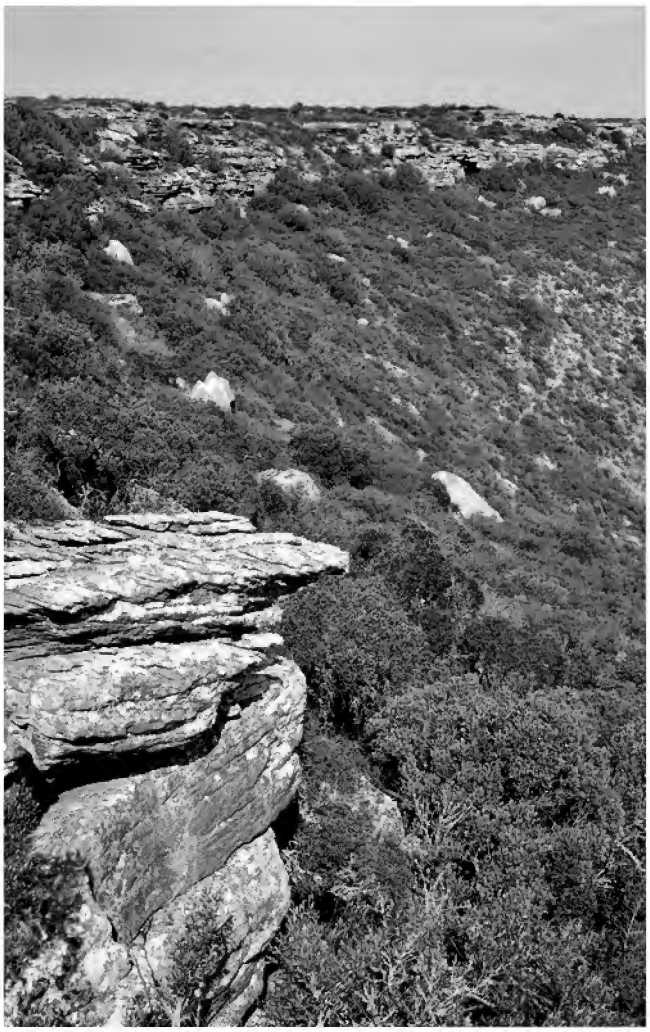

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Figure 5.38 SKn 6 Kamiesberg Mountains Shrubland: Southern variation of the mesic (tall) shubland with *Euclea*, *Diospyros* and *Rhus* dominant on the subescarpment rim of the Noord Bokkeveld on the Farm Perdekraal, north of Nieuwoudtville (border of the Northern Cape and Western Cape Provinces).

aethiopicum, *Asparagus capensis* var. *capensis*, *Ballota africana*, *Chrysocoma ciliata*, *Clutia imbricata*, *Eriocephalus brevifolius*, *E. microcephalus*, *Euryops tenuissimus*, *Helichrysum scabrum*, *Hermannia cuneifolia*, *H. disermifolia*, *Indigofera pungens*, *Maytenus oleoides*, *Pegolettia retrofracta*, *Pelargonium antidysentericum*, *P. praemorsum*, *Pentzia incana*, *Pharnaceum albens*, *Rhus horrida*, *Selago divaricata*, *Senecio cotyledonis*, *Wahlenbergia thunbergiana*, *Wiborgia mucronata*. Woody Succulent Climber: *Sarcostemma viminale*. Woody Climber: *Microloma sagittatum*. Herbaceous Parasitic Climber: *Cassytha ciliolata*. Herbs: *Ursinia cakilefolia* (d), *Amellus alternifolius*, *Anchusa capensis, Galium tomentosum*, *Heliophila crithmifolia*, *Hemimeris racemosa*, *Jamesbrittenia glutinosa*, *Nemesia affinis*, *Plantago cafra*, *Rhynchopsidium pumilum*, *Senecio sisymbriifolius*, *Silene undulata*, *Sutera foetida*, *Trichogyne paronychioides*, *Ursinia anthemoides* subsp. *anthemoides*. Geophytic Herbs: *Asplenium cordatum*, *Cyanella hyacinthoides*, *Oxalis obtusa*, *Spiloxene scullyi*. Succulent Herb: *Crassula muscosa*. Graminoids: *Chaetobromus involucratus* subsp. *dregeanus*, *Cymbopogon pospischilii*, *Ehrharta barbinodis*, *E. calycina*, *E. longiflora*, *Ficinia nigrescens*, *Fingerhuthia africana*, *Schismus inermis*.

Biogeographically Important Taxa ([NQ]Namaqualand endemic, [K]Kamiesberg endemic, [N]Northern distribution limit, [F]Fynbos element) Low Shrubs: *Antithrixia flavicoma*[K], *Diosma acmaeophylla*[F], *Elytropappus rhinocerotis*[F], *Felicia diffusa* subsp. *khamiesbergensis*[K], *Lobostemon argenteus*[F], *L. glaucophyllus*[F], *Melianthus pectinatus*[NQ], *Muraltia rigida*[K], *Oftia revoluta*[NQ], *Pteronia leptospermoides*[NQ], *Salvia dentata*[NQ], *Stachys flavescens*[NQ]. Herbs: *Gorteria diffusa* subsp. *calendulacea*[NQ], *Lotononis acutiflora*[K]. *Nemesia gracilis*[N]. Geophytic Herbs: *Babiana dregei*[NQ], *Disa macrostachya*[K]. Succulent Herb: *Cleretum papulosum* subsp. *schlechteri*[NQ]. Graminoids: *Aristida dasydesmis*[NQ], *Ischyrolepis gaudichaudiana*[F], *Pentaschistis patula*[F], *Tribolium echinatum*[F].

Endemic Taxon Low Shrub: *Muraltia namaquensis*.

Conservation Least threatened and only about 2% statutorily conserved in Namaqua National Park and small patches also in Goegap and Oorlogskloof Nature Reserves. Target 28%. Transformation by cultivation is of no importance due to poor accessibility or overall unsuitability of the habitats to agriculture. Erosion is moderate (50%), low (30%) and high in places (20%), mainly due to steep terrain.

Remark The southernmost part of this vegetation is a narrow subkrantz strip on west-facing (fog-catching) slopes of the northern Bokkeveld Escarpment (between the Farms Perdekraal north of Nieuwoudtville and Waterval east of Vanrhynsdorp). Unlike in the central Namaqualand, where the major patches of SKn 6 Kamiesberg Mountains Shrubland occur on granite and gneiss, the Noord Bokkeveld patch is limited to boulder fields and screes built of hard Nardouw sandstones. *Rhus undulata, Didelta spinosa, Euclea tomentosa* and other tall shrubs dominate this shrubland, squeezed between renosterveld (on the upper boundary) and low Succulent Karoo shrublands (on the lower boundary). Despite some structural characteristics, floristic composition as well as its position in vegetation complexes, there are a number of idiosyncrasies suggesting that the Noord Bokkeveld patch of the SKn 6 Kamiesberg Mountains Shrubland is a vegetation unit in its own right.

References Le Roux (1984), Theron et al. (1993), Van Rooyen (2002).

Namaqualand Sandveld

SKs 1 Richtersveld Coastal Duneveld

VT 34 Strandveld of West Coast (99%) (Acocks 1953). LR 55 Strandveld Succulent Karoo (85%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Broad belt of 1–12 km along Atlantic Ocean coast from a point between the Boegoe Twins and Alexander Bay to about halfway between Port Nolloth and Kleinzee. The north-south extension is 104 km. Altitude 0–200 m.

Vegetation & Landscape Features Generally flat with some large, gently rolling hills. Only the Boegoe Twins south of Alexander Bay form steeper rocky slopes. Relatively homogeneous vegetation covers fairly stable sand sheets. Depth of sand and soil crust define character of habitat types. On the active dunes, depending on the aspects of the slopes and on the phase of deflation and sedimentation, different plant communities occur. *Stoeberia utilis* often grows on the dune crests, while *S. beetzii* is found more on stabilised sand sheets. *Lampranthus hoerleinianus* and *Cladoraphis cyperoides* are pioneers settling in habitats created by recent sand deflation.

Geology & Soils Wind-blown white sands of coastal origin overlying rocks belonging to the Holgat and Grootderm Formations of the Gariep Supergroup. Especially around Port

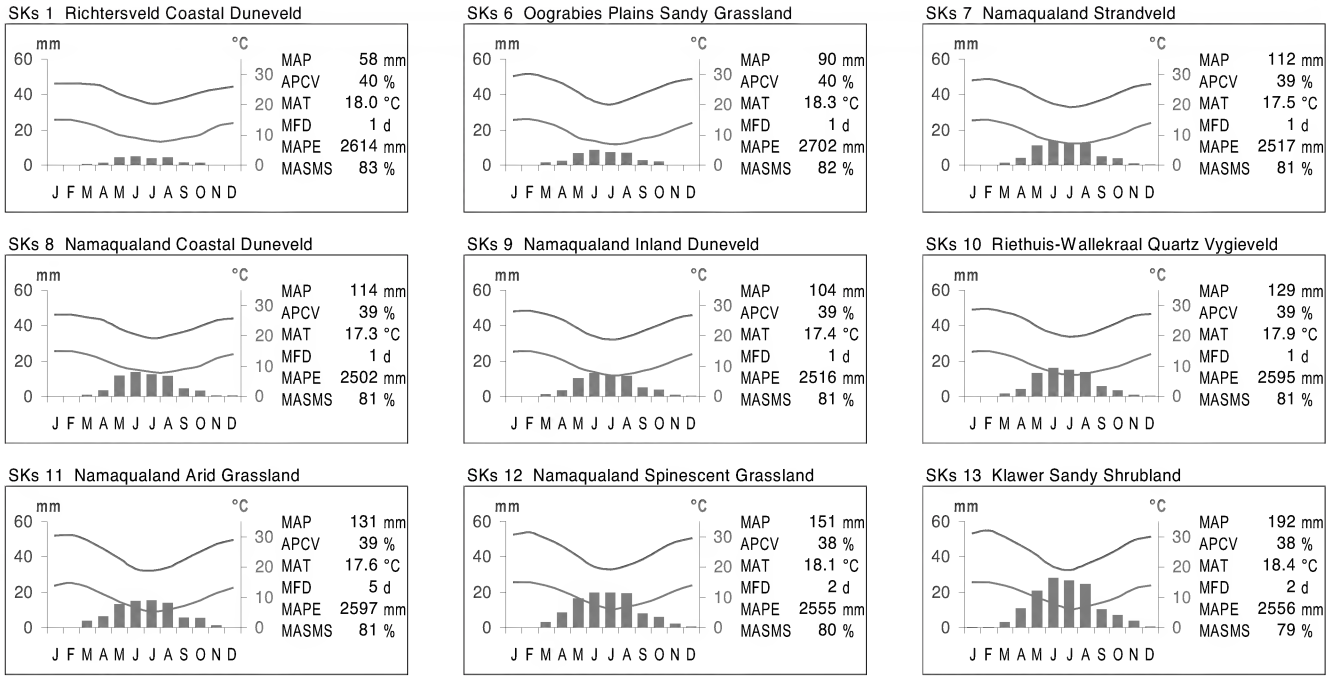

Figure 5.39 Climate diagrams of selected Namaqualand Sandveld Bioregion units. Blue bars show the median monthly precipitation. The upper and lower red lines show the mean daily maximum and minimum temperature respectively. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days (days when screen temperature was below 0°C); MAPE: Mean Annual Potential Evaporation; MASMS: Mean Annual Soil Moisture Stress (% of days when evaporative demand was more than double the soil moisture supply).

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Figure 5.40 SKs 1 Richtersveld Coastal Duneveld: *Othonna sedifolia* community on deep white sand dunes (near Holgat River on the road between Port Nolloth and Alexander Bay).

Nolloth and north of the Holgat River mouth active dune fields can be found. The dominant land type is Ha.

Climate Extreme wind speeds and sand blasting from the south. High storm frequency. MAP is 50–80 mm, with winter rains clearly predominant. Medium to high frequency of sea fog. No incidence of frost. See also climate diagram for SKs 1 Richtersveld Coastal Duneveld (Figure 5.39).

Important Taxa Succulent Shrubs: *Cephalophyllum ebracteatum* (d), *Euphorbia mauritanica* (d), *Othonna sedifolia* (d), *Salsola nollothensis* (d), *Zygophyllum morgsana* (d), *Aloe microstigma*, *Amphibolia rupis-arcuatae*, *Didelta carnosa* var. *tomentosa*, *Drosanthemum luederitzii*, *Euphorbia burmannii*, *E. tuberculata* var. *macowani*, *Hypertelis angrae-pequenae*, *Jordaaniella cuprea*, *J. spongiosa*, *Lampranthus hoerleinianus*, *Lycium tetrandrum*, *Manochlamys albicans*, *Salsola tuberculata*, *Senecio radicans*, *Stoeberia utilis*, *Tylecodon schaeferianus*, *Zygophyllum clavatum*, *Z. cordifolium*. Low Shrubs: *Asparagus capensis* var. *litoralis* (d), *Atriplex vestita* var. *appendiculata*, *Heliophila carnosa*, *Jamesbrittenia fruticosa*, *Pteronia glabrata*, *P. onobromoides*. Woody Succulent Climber: *Pelargonium fulgidum*. Herb: *Grielum grandiflorum*. Geophytic Herb: *Babiana thunbergii*. Succulent Herbs: *Aloe arenicola*, *Fenestraria rhopalophylla*, *Psilocaulon dinteri*. Parasitic Herb: *Harveya squamosa*. Graminoids: *Cladoraphis cyperoides* (d), *Chaetobromus involucratus* subsp. *dregeanus*, *Stipagrostis ciliata*.

Biogeographically Important Taxa ([NQ]Namaqualand endemic, [R]Richtersveld endemic) Succulent Shrubs: *Stoeberia beetzii*[NQ] (d), *Amphibolia succulenta*[R], *Arctotis scullyi*[NQ].

Endemic Taxa Succulent Shrub: *Crassula brevifolia* subsp. *psammophila*. Low Shrub: *Bassia dinteri*.

Conservation Least threatened. Target 26%. None conserved in statutory conservation areas. Almost 10% transformed mainly by diamond mining.

Remark *Acanthosicyos horridus*, a typical Namib Desert element, occurs only on the mobile dunes northeast of Port Nolloth. The two rocky outcrops of the Boegoe Twins form two fog oases within the vegetation unit housing *Tylecodon schaeferianus*, *Senecio phonolithicus*, *Jordaaniella spongiosa* and *Cephalophyllum ebracteatum*. *Aloe framesii, Jordaaniella cuprea* and *J. spongiosa* are regional endemics shared with the neighbouring coastal units.

References Van Jaarsveld (1981), Jürgens (1991, 2004), Jürgens et al. (1997), Van Wyk & Smith (2001).

SKs 2 Northern Richtersveld Yellow Duneveld

VT 31 Succulent Karoo (74%) (Acocks 1953). LR 57 Lowland Succulent Karoo (92%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Richtersveld, band some 5–25 km wide east of the coastline, stretching over 45 km from south of Brandkaros in the north to the Holgat River in the south. The altitude of the unit varies from about 50–300 m.

Vegetation & Landscape Features Most of the area is covered by flat sand shields, often interrupted by dunes, which normally form flat whale-backs. Steep dune crests and dune valleys form only rarely—here the vegetation mirrors different topographic units: the dune tops are covered with *Stoeberia utilis*, while the interdune valleys are dominated by *Brownanthus pseudoschlichtianus, B. arenosus, Cheiridopsis robusta* and *Cephalophyllum ebracteatum*.

Geology & Soils Mainly yellow, wind-blown sands of coastal origin, older than the white dune sands found further west—an ancient mobile dune field, which became stabilised as a consequence of improving climate conditions and increase of vegetation cover after the last glaciation. The structure of south-north-oriented dune ridges and accompanying valley systems is still visible, but the local processes of erosion and sedimentation have resulted in formation of relatively saline valleys with silty or loamy soil. Currently wind erosion is active only to a very limited extent. Ah is the dominant land type, while Ai land type is of subordinate importance.

Climate MAP is 50–70 mm with mainly winter rainfall. High frequency of coastal fog. Extreme wind speeds and sand blasting from the south. Storms occur frequently. Frost is very rare.

Important Taxa Succulent Shrubs: *Euphorbia burmannii* (d), *E. chersina* (d), *E. mauritanica* (d), *Othonna cylindrica* (d), *Aridaria serotina*, *Cephalophyllum ebracteatum*, *Cheiridopsis robusta*, *Didelta carnosa* var. *tomentosa*, *Hypertelis salsoloides*, *Jordaaniella cuprea, Lampranthus hoerleinianus*, *Salsola tuberculata*, *Zygophyllum morgsana*. Low Shrubs: *Asparagus capensis* var. *capensis*, *Lebeckia cinerea*, *L. multiflora*. Herbs: *Grielum humifusum*, *Oncosiphon piluliferum*. Geophytic Herb: *Trachyandra falcata*. Succulent Herb: *Brownanthus arenosus* (d). Graminoid: *Cladoraphis cyperoides* (d).

Biogeographically Important Taxa ([NQ]Namaqualand endemic, [G]Gariep endemic, [R]Richtersveld endemic) Succulent Shrubs: *Amphibolia succulenta*[R], *Eberlanzia sedoides*[G], *Phyllobolus decurvatus*[NQ]. Succulent Herbs: *Brownanthus pseudoschlichtianus*[G], *Mesembryanthemum pellitum*[G].

Conservation Least threatened. Target 26%. None conserved in statutory conservation areas. Slightly transformed by mining. At present no major threat to the unit has been identified.

Remark The unit is characterised by high beta diversity due to dune structures, especially high differences between mobile and fixed sand areas (the latter are partly covered by heuweltjies). *Jordaaniella cuprea* and *J. spongiosa* are regional endemics shared with the neighbouring coastal units.

References Van Jaarsveld (1981), Jürgens (1991, 2004), Jürgens et al. (1997), Oguz (2000), Stöcker (2000), Van Wyk & Smith (2001), Nußbaum (2003), Oguz et al. (2004).

SKs 3 Southern Richtersveld Yellow Duneveld

VT 34 Strandveld of West Coast (84%) (Acocks 1953). LR 57 Lowland Succulent Karoo (53%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Richtersveld—a strip running parallel to, and roughly 5–12 km from, the coastline from the Holgat River in the north to almost level with Port Nolloth in the south. A small isolated patch also found east of Vyftienmyl se Berge. The altitude varies from 50–300 m.

Vegetation & Landscape Features Flat to undulating sand shields, in places also with dunes forming flat whale-backs. The appearance of vegetation in this unit is similar to that of the SKs 2 Northern Richtersveld Yellow Duneveld, but the southern unit is much denser due to higher moisture levels, and it is also more species-rich.

Geology & Soils Yellow wind-blown sands, mainly of marine origin. Soils vary as to the soil depth covering various duricrusts, mainly calcrete. Ah is the dominant land type, while Ha land type is also present.

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Figure 5.41 SKs 2 Northern Richtersveld Yellow Duneveld: Richtersveld Sandveld with *Brownanthus pseudoschlichtianus* and *Cladoraphis cyperoides*.

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Figure 5.42 SKs 3 Southern Richtersveld Yellow Duneveld: Succulent-rich strandveld vegetation on stabilised dunes northwest of Port Nolloth (Richtersveld).

Climate MAP is 55–80 mm of winter rainfall. Low to medium average maximum temperatures. Wind and sand blasting from the south. Coastal fog also occurs. No incidence of frost.

Important Taxa Succulent Shrubs: *Euphorbia burmannii* (d), *E. chersina* (d), *E. mauritanica* (d), *Othonna cylindrica* (d), *Zygophyllum morgsana* (d), *Aloe microstigma*, *Aridaria serotina*, *Cheiridopsis robusta*, *Didelta carnosa* var. *tomentosa*, *Euphorbia decussata*, *E. ephedroides* var. *ephedroides*, *Jordaaniella cuprea*, *J. spongiosa*, *Manochlamys albicans*, *Salsola tuberculata*, *Tylecodon paniculatus*. Low Shrubs: *Tripteris oppositifolia* (d), *Asparagus capensis* var. *capensis*, *Atriplex vestita* var. *appendiculata*, *Pteronia glabrata*, *P. onobromoides*. Herbs: *Capnophyllum africanum*, *Grielum humifusum*. Geophytic Herb: *Trachyandra falcata*. Succulent Herbs: *Aloe arenicola*, *Psilocaulon dinteri*. Graminoids: *Chaetobromus involucratus* subsp. *dregeanus* (d), *Cladoraphis cyperoides* (d), *Stipagrostis ciliata* (d).

Biogeographically Important Taxa ([NQ]Namaqualand endemic, [G]Gariep endemic, [R]Richtersveld endemic) Succulent Shrubs: *Stoeberia beetzii*[NQ] (d), *Amphibolia succulenta*[R], *Arctotis scullyi*[NQ]. Succulent Herb: *Mesembryanthemum pellitum*[G].

Conservation Least threatened. Target 26%. None conserved in statutory conservation areas. More than 3% transformed mostly by mining, especially in the southern and western parts.

Remark *Jordaaniella cuprea* and *J. spongiosa* are regional endemics shared with the neighbouring coastal units.

References Van Jaarsveld (1981), Jürgens (1991, 2004), Jürgens et al. (1997), Van Wyk & Smith (2001), Nußbaum (2003).

SKs 4 Richtersveld Sandy Coastal Scorpionstailveld

VT 31 Succulent Karoo (100%) (Acocks 1953). LR 57 Lowland Succulent Karoo (100%) (Low & Rebelo 1996).

Distribution Northern Cape Province: A fragmented band running parallel to the coast 8 to 28 km inland, from a northern boundary at the southwestern corner of the Annisvlakte to the Holgat River, and then for some 30 km southwards. Further this unit is found from just north of the road between Alexander Bay and Oograbies in a southern direction halfway between Port Nolloth and Kleinzee. The unit covers 103 km along the north-south axis. Altitude ranging from 100–400 m.

Vegetation & Landscape Features Slightly flatter compared to the SKr 7 Northern Richtersveld Scorpionstailveld. The boundaries of this unit are clearly visible on satellite and aerial images, characterised by a darker colour, which is created by the intense biological soil surface crusts. Within this unit, habitat variability is mainly controlled by soil types and age of vegetation, which again are controlled by the proportion of wind-blown sands, and partly also by grazing and mining. The matrix of the unit is formed by more loamy sands with old and stable vegetation, often dominated by *Brownanthus pseudoschlichtianus* and mixed with co-dominant species like *Stoeberia beetzii*, *Othonna cylindrica*, *Lebeckia multiflora*, *Cephalophyllum ebracteatum* and *Phyllobolus decurvatus*.

Geology & Soils Sandy loams, partly covered by yellow and red wind-blown sands, probably of coastal origin. This unit clearly shows an increase in the silt texture class (ca. 20%), which is linked to an increase in pH, compared to the neighbouring units. Within this unit, the surface cover of biological soil crusts at the soil surface reaches maximum values for the Richtersveld coastal plain (80–90%). The hypothesis is proposed that this unit is controlled by maximum silt deposition (desert margin loess) and minimum disturbance, compared to the neighbouring units of the coastal plain. Ah land type is absolutely dominant.

Climate MAP 60–100 mm, with mainly winter rainfall. Coastal fog also occurs. High wind speeds occur, but are less frequent and weaker than in the SKs 2 Northern Richtersveld Yellow Duneveld. Frost is very rare.

Important Taxa Succulent Shrubs: *Cephalophyllum ebracteatum* (d), *Othonna cylindrica* (d), *Aridaria serotina*, *Cheiridopsis robusta*, *Euphorbia burmannii*, *E. chersina*, *E. mauritanica*, *Hypertelis salsoloides*, *Zygophyllum morgsana*. Low Shrubs: *Lebeckia multiflora* (d), *Asparagus capensis* var. *capensis*. Herb: *Oncosiphon piluliferum*. Geophytic Herb: *Trachyandra falcata*. Graminoid: *Cladoraphis cyperoides* (d).

Biogeographically Important Taxa ([NQ]Namaqualand endemic, [G]Gariep endemic) Succulent Shrubs: *Phyllobolus decurvatus*[NQ] (d), *Stoeberia beetzii*[NQ] (d), *Eberlanzia ebracteata*[G]. Succulent Herbs: *Brownanthus pseudoschlichtianus*[G] (d), *Mesembryanthemum pellitum*[NQ].

Conservation Least threatened. Target 26%. None conserved in statutory conservation areas. Very little of the area has been transformed. There is no information available allowing for an estimation of the past and present role of small stock grazing.

Remark Where sand layers occur, larger islands of the Othonnion cylindricae are found (Jürgens 2004).

References Van Jaarsveld (1981), Jürgens (1991, 2004), Jürgens et al. (1997), Oguz (2000), Van Wyk & Smith (2001), Nußbaum (2003), Oguz et al. (2004).

SKs 5 Richtersveld Red Duneveld

VT 31 Succulent Karoo (96%) (Acocks 1953). LR 57 Lowland Succulent Karoo (85%) (Low & Rebelo 1996).

Distribution Northern Cape Province: A band running parallel to the coastline, east of the SKs 4 Richtersveld Sandy Coastal Scorpionstailveld, and forming the eastern margin of the Richtersveld Sandveld, running from the Annisvlakte in the north southwards and reaching its southern limit northwest of the Oograbies Mountains (east of Port Nolloth). Usually not closer than 12–26 km from the coast. Altitude varies from 200–500 m.

Vegetation & Landscape Features High dune aggregates (oriented in a north-south direction), which again carry smaller dunes (mainly west-east-orientated). Habitat variability is mainly controlled by exposure and by dynamics of sand movement as well as by age of subsequent succession phases of vegetation. Large parts of the red dunes are dominated by tall grasses and vegetation of tall shrubs with dense *Lebeckia cinerea*-dominated thickets over some large areas. Otherwise *Cladoraphis spinosa*, *Brownanthus arenosus*, *Asparagus capensis* and *Stipagrostis ciliata* are dominant and are associated with the relatively high water input caused by orogenic rains of the nearby mountain ranges in conjunction with the coarse soil texture that supports effective water storage. In disturbed places, there is often a high cover of *Conicosia pugioniformis*, *Arctotis fastuosa* and *Foveolina dichotoma*. The slopes exposed to the west show a strong admixture of taxa of the SKs 2 Northern Richtersveld Yellow Duneveld (e.g. *Stoeberia beetzii* and *S. utilis*), and in some parts *Stipagrostis lutescens* is an important element.

Geology & Soils Dark red sands with their thick iron coating are interpreted as old sands, which have experienced a longer period without major mechanical or chemical disturbance. The red dunes show the lowest admixture of silt and clay, compared to the other dune types in the Richtersveld. The pH is around 6.5 as compared to the average of 8.0 to 8.5 found in the neighbouring units. Salt content and electrical conductivity are the lowest (10 µS), hence 10 to 100 times lower than elsewhere in the region. The land types Af and Ah are almost equally important, while Ae is less important.

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Figure 5.43 SKs 5 Richtersveld Red Duneveld: The northernmost reaches of the red duneveld with *Euphorbia gummifera*. The grass in the foreground is *Stipagrostis capensis*, while the larger tufts further back belong to *S. lutescens*.

Climate Winter-rainfall with estimated MAP 50–100 mm. Maximum temperatures are lower than further inland. Coastal fog also occurs, and frost is very rare.

Important Taxa Succulent Shrubs: *Euphorbia ephedroides* var. *ephedroides* (d), *Othonna cylindrica* (d), *Salsola tuberculata*. Low Shrubs: *Asparagus capensis* var. *capensis* (d), *Lebeckia multiflora* (d), *Galenia crystallina*, *Lebeckia cinerea*. Herbs: *Arctotis fastuosa*, *Foveolina dichotoma*. Succulent Herbs: *Brownanthus arenosus* (d), *Conicosia elongata*, *C. pugioniformis* subsp. *alborosea*. Graminoids: *Cladoraphis spinosa* (d), *Stipagrostis ciliata* (d), *S. lutescens*.

Biogeographically Important Taxa ([NQ]Namaqualand endemic, [G]Gariep endemic) Succulent Shrubs: *Euphorbia dregeana*[G], *Stoeberia beetzii*[NQ].

Conservation Least threatened. Target 26%. None conserved in statutory conservation areas. There is no information available on which to base an estimation of the past and present role of small stock grazing.

Remark An important difference from all other units of the coastal Sandveld (e.g. SKs 1 Richtersveld Coastal Duneveld and SKs 2 Northern Richtersveld Yellow Duneveld) is its low salinity.

References Van Jaarsveld (1981), Jürgens (1991, 2004), Jürgens et al. (1997), Oguz (2000), Stöcker (2000), Oguz et al. (2004).

SKs 6 Oograbies Plains Sandy Grassland

VT 31 Succulent Karoo (100%) (Acocks 1953). LR 57 Lowland Succulent Karoo (100%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Richtersveld—central and lower portion of the large plains east of Vyftienmyl se Berge, starting at about ca. 25 km east of Port Nolloth and continuing northeastwards for another 25 km. At relatively narrow range of altitudes from 180–300 m.

Vegetation & Landscape Features Flat or slightly undulating landscape with some dune ridges. Main habitats are dune formations and flat sand sheets. The main vegetation feature is the relatively homogeneous grassy shrubland or shrubby spinescent grassland dominated by *Cladoraphis spinosa* and *Stipagrostis ciliata*. In different seasons and years (probably as a consequence of rainfall availability) the biomass of this unit can vary and show dominance of either grasses or leaf-succulent chamaephytes and annuals.

Geology & Soils Stabilised, deep, red, aeolian sands forming fossil dunes and overlying gneiss of the Namaqualand Metamorphic Complex forming active dunes in places. Ai is the dominant land type, with Ae land type playing a minor role.

Climate MAP estimated to range from 80–120 mm, with winter rainfall clearly dominant. Frequent fog occurrence. Incidence of frost is very rare. See also climate diagram for SKs 6 Oograbies Plains Sandy Grassland (Figure 5.39).

Important Taxa Succulent Shrubs: *Othonna cylindrica* (d), *Zygophyllum morgsana*. Low Shrubs: *Hermannia paucifolia*, *Lebeckia cinerea*, *L. mul-*

M. Pfosser

Figure 5.44 SKs 6 Oograbies Plains Sandy Grassland: *Cladoraphis spinosa* with *Salsola* shrubs and fragrant *Bulbine frutescens* in spring on the Oograbies Plains, east of Port Nolloth (southern Richtersveld, Northern Cape).

coast only near the river mouths of the Buffels River, Swartlintjies River, Spoeg River, Bitter River and Groen River. South of Abraham Villiersbaai (south of Groen River mouth) Namaqualand Strandveld descends to the coast and continues as an unequally broad band as far south as Donkins Bay (north of Lamberts Bay). In the south it also reaches deeply inland along the Groen and Swartdoorn Rivers as well as along the lower stretches of the Olifants River. Altitude 20–380 m.

Vegetation & Landscape Features Flat to slightly undulating landscape of coastal peneplain. Vegetation is low species-rich shrubland dominated by a plethora of erect and creeping succulent shrubs (*Cephalophyllum, Didelta, Othonna, Ruschia, Tetragonia, Tripteris, Zygophyllum*) as well as nonsucculent shrubs (*Eriocephalus, Lebeckia, Pteronia, Salvia*). Annual mixed with perennial flora can present spectacular displays in wet years.

tiflora, *Psilocaulon subnodosum*. Herbs: *Coelanthum grandiflorum*, *Lyperia tristis*. Geophytic Herbs: *Bulbine frutescens* (d), *Gethyllis lanuginosa*, *Massonia depressa*, *Trachyandra falcata*. Graminoids: *Cladoraphis spinosa* (d), *Stipagrostis ciliata* (d).

Biogeographically Important Taxon (Namaqualand endemic) Herb: *Trichogyne lerouxiae*.

Conservation Least threatened. Target 26%. None conserved in statutory conservation areas and little transformed. Based on the available data, no special conservation status is proposed from a botanical point of view.

Remark In places, large mobile dunes with higher water storage capacity support larger shrubs and relict populations of the tree *Parkinsonia africana*. The northernmost populations of a number of species typical of the dune fields of the West Coast are found in this unit.

Geology & Soils Quaternary stabilised aeolian, deep, red or yellowish red, stable dunes and deep sand overlying marine sediments and granite gneisses. Sometimes weakly defined scattered heuweltjies are found further away from the sea. Unstable white sand dune plumes originate from the river mouths and extend north- and northeastwards up to 25 km inland. Dunes become slightly more stable north of Kleinzee. The area is a combination of Ah, Ae, Af, Ai and Ag land types.

Climate Arid, winter-rainfall area with MAP of 112 mm. Almost all the rainfall occurs from May to August and almost always no rainfall in December and February. Frost is a rare event. Lowest temperatures in winter are 8–10°C and the highest temperatures in the summer just below 30°C. See also climate diagram for SKs 7 Namaqualand Strandveld (Figure 5.39).

References Van Jaarsveld (1981), Jürgens (1991, 2004), Jürgens et al. (1997).

SKs 7 Namaqualand Strandveld

VT 31 Succulent Karoo (67%) (Acocks 1953). LR 57 Lowland Succulent Karoo (70%) (Low & Rebelo 1996).

Distribution Northern and Western Cape Provinces: Namaqualand Sandveld—from Gemboksvlei (at southern foothills of the Vyftienmyl se Berge in southern Richtersveld as far south as Donkins Bay (south of Doringbaai). Especially in the northern region (plains north and south of Buffels River) this unit penetrates deeply inland (40 km in places). Most of the area is situated deep inland (isolated from the coast by a belt of SKs 8 Namaqualand Coastal Duneveld) and approaching the

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Figure 5.45 SKs 7 Namaqualand Strandveld: Isolated granite outcrops in the Molyneux Reserve at Kleinzee (Namaqualand coast) with sparse succulent shrubland (with prominent *Aloe framesii*) housing a number of local endemics and species still pending description.

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Figure 5.46 SKs 7 Namaqualand Strandveld: Well-developed coastal shrubland south of Doringbaai (southern Namaqualand), with bushes of an undescribed species of *Afrolimon* (Plumbaginaceae).

Important Taxa Succulent Shrubs: *Didelta carnosa* var. *carnosa* (d), *Euphorbia burmannii* (d), *Othonna cylindrica* (d), *Ruschia brevibracteata* (d), *Salsola nollothensis* (d), *Tetragonia fruticosa* (d), *T. spicata* (d), *Zygophyllum morgsana* (d), *Adromischus mammillaris*, *Aridaria noctiflora* subsp. *noctiflora*, *Euphorbia tuberculata* var. *macowani*, *Exomis microphylla* var. *axyrioides*, *Manochlamys albicans*, *Othonna sedifolia*, *Salsola namibica*, *Sarcocaulon flavescens*, *Senecio sarcoides*, *Stoeberia utilis*, *Tylecodon paniculatus*, *T. reticulatus*, *T. wallichii* subsp. *wallichii*. Tall Shrubs: *Nylandtia spinosa*, *Putterlickia pyracantha*. Low Shrubs: *Galenia fruticosa* (d), *Pteronia onobromoides* (d), *Tripteris oppositifolia* (d), *Zygophyllum spinosum* (d), *Asparagus capensis* var. *capensis*, *Berkheya fruticosa*, *Chrysocoma longifolia*, *Galenia secunda*, *Helichrysum cylindriflorum*, *H. hebelepis*, *Hermannia cuneifolia*, *H. multiflora*, *H. trifurca*, *Hirpicium alienatum*, *Justicia cuneata* subsp. *latifolia*, *Lebeckia halenbergensis*, *L. spinescens*, *Limeum africanum*, *Nenax arenicola*, *Pelargonium praemorsum*, *Pharnaceum aurantium*, *P. confertum*, *Pteronia divaricata*, *Salvia lanceolata*, *Tripteris sinuata*, *Wiborgia fusca* subsp. *fusca*. Semiparasitic Shrub: *Thesium spinosum*. Woody Climbers: *Asparagus fasciculatus*, *A. retrofractus*, *Microloma sagittatum*. Herbs: *Oncosiphon suffruticosum* (d), *Amellus microglossus*, *Arctotheca calendula*, *Gazania jurineifolia* subsp. *scabra*, *Heliophila coronopifolia*, *Hermannia althaeifolia*, *Leidesia procumbens*, *Nemesia ligulata*, *Osteospermum pinnatum*, *Rhynchopsidium pumilum*. Geophytic Herbs: *Bulbine frutescens*, *Oxalis annae*, *O. pes-caprae*, *O. purpurea*. Succulent Herbs: *Aloe arenicola*, *Conicosia pugioniformis* subsp. *pugioniformis*, *Psilocaulon dinteri*. Graminoids: *Ehrharta calycina* (d), *Schismus barbatus* (d), *Stipagrostis zeyheri* subsp. *macropus* (d), *Chaetobromus involucratus* subsp. *dregeanus*, *Cladoraphis cyperoides*, *Ehrharta barbinodis*, *E. delicatula*, *E. triandra*, *Pentaschistis airoides*, *Willdenowia incurvata*.

Biogeographically Important Taxa ([NQ]Namaqualand endemic, [N]Northern distribution limit) Succulent Shrubs: *Othonna arborescens*[N], *Vanzijlia annulata*[NQ]. Tall Shrubs: *Euclea racemosa*[N], *Rhus glauca*[N]. Low Shrubs: *Aspalathus spinescens* subsp. *lepida*[N], *Dischisma struthioloides*[NQ], *Lebeckia grandiflora*[N], *Leucoptera nodosa*[NQ], *Lobostemon pearsonii*[N], *Pelargonium crassipes*[NQ], *Pteronia fastigiata*[N], *Salvia africana-lutea*[N]. Semiparasitic Shrub: *Thesium elatius*[N]. Herbaceous Climber: *Indigofera procumbens*[N]. Herbs: *Zaluzianskya villosa*[N] (d), *Diascia nana*[N], *Indigastrum costatum* subsp. *macrum*[N], *Kedrostis psammophylla*[NQ], *Manulea altissima* subsp. *longifolia*[NQ], *Nemesia versicolor*[N], *Trichogyne lerouxiae*[NQ]. Geophytic Herbs: *Ferraria foliosa*[N] (shared with FS 1 Lambert's Bay Strandveld), *Gethyllis polyanthera*[N], *Holothrix grandiflora*[N], *Lachenalia bulbifera*[N], *Oxalis compressa*[N], *O. flava*[N], *O. pulchella* var. *glauca*[NQ]. Succulent Herb: *Othonna gymnodiscus*[N], *Tetragonia pillansii*[NQ]. Graminoids: *Ehrharta ramosa* subsp. *aphylla*[N], *E. villosa* var. *maxima*[N], *Thamnochortus lucens*[N].

Endemic Taxa Succulent Shrubs: *Lampranthus suavissimus*, *Tylecodon decipiens*, *T. fragilis*. Low Shrubs: *Afrolimon* sp. nov. (*Mucina 210103/1* STEU), *Gorteria* sp. nov. (*Le Roux, Karis & Mucina 050905/2* STEU), *Sutera multiramosa*. Geophytic Herbs: *Lachenalia valeriae, Romulea sinispinosensis*.

Conservation The threats to the vegetation are coastal mining for heavy metals currently at the Brand-se-Baai area east of Lutzville, and this mining is extending at an alarming rate. Target 26%. None of the area is conserved in a statutory conservation area, but some small private reserves (Bojaansklip, Donkins Bay, Doorspring, Molyneux, Zeven Puts) protect some of its vegetation. About 10% of the area has been transformed. This vegetation is generally subject to extensive grazing. Alien *Acacia* species may become a problem, especially in the southern part of the area. Erosion is very low.

Remark The considerable geographic extent of this unit (spanning 2° 36′ of latitude) suggests that a more detailed floristic-biogeographical and vegetation-ecological analysis of data (much still to be collected) would result in splitting SKs 7 Namaqualand Strandveld into at least new northern and southern vegetation units in their own right.

References Boucher & Le Roux (1989, 1993), De Villiers et al. (1994, 1999, 2001, 2003), De Villiers (2000), Eccles (2000), Eccles et al. (1999, 2001).

SKs 8 Namaqualand Coastal Duneveld

VT 34 Strandveld of West Coast (77%) (Acocks 1953). LR 55 Strandveld Succulent Karoo (63%) (Low & Rebelo 1996).

Distribution Northern and Western Cape Provinces: Namaqualand Sandveld, coastal plains on or very near the sea, from Deurloopbaai (south of Port Nolloth) to Abraham Villiersbaai (south of the Groen River mouth). Altitude range 10–260 m.

Vegetation & Landscape Features Coastal peneplain with semimobile sand plains to highly mobile, sharp, angular dune plumes usually north of the estuaries. Vegetation is dwarf shrubland dominated by erect succulent shrubs (*Didelta, Othonna, Ruschia, Tetragonia, Tripteris, Zygophyllum*) as well as nonsucculent shrubs (*Eriocephalus, Lebeckia, Pteronia, Salvia*). Spiny grasses (*Cladoraphis*) are a common sight on wind-blown semistable dunes, with 1–2 m erect to spreading shrubs mostly with malacophyllous leaves protected from the wind between dunes.

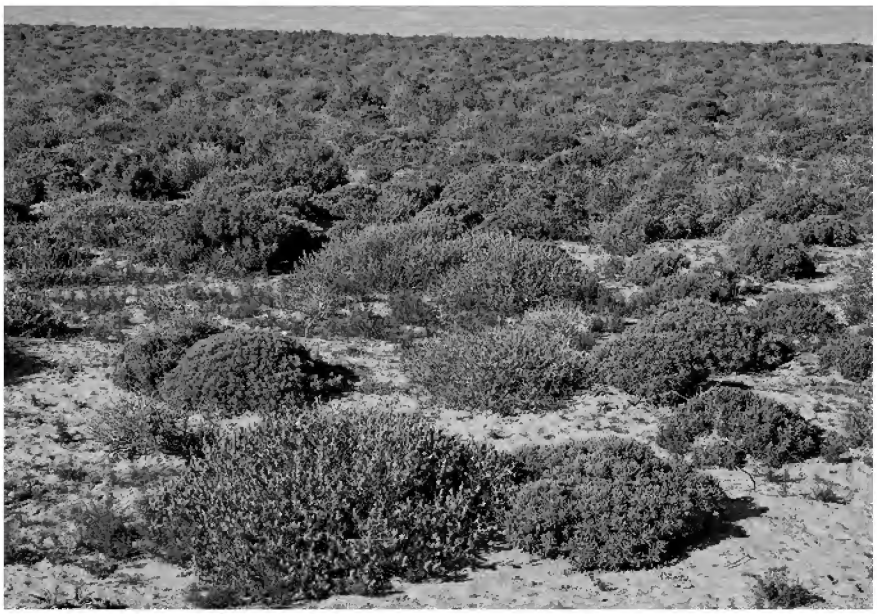

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Figure 5.47 SKs 8 Namaqualand Coastal Duneveld: Coastal succulent shrubland with low hemispheric shrubs such as *Othonna cylindrica* (Asteraceae) and *Manochlamys albicans* (Chenopodiaceae) at the road between Kleinzee and Koingnaas on the Namaqualand diamond-bearing coast.

Annual flora can present spectacular displays in wet years, but unlike the usual well-known displays of Namaqualand annual flowers, this display is produced mostly by perennial species.

Geology & Soils Quaternary, aeolian, yellowish or grey to white, up to 1.5 m deep fine sands forming mobile as well as stabilised coastal dune fields and overlying Tertiary sediments of marine origin. Ai land type covers about two thirds of the area and it is followed by Ha land type.

Climate Arid, winter-rainfall area with MAP only 114 mm and almost all rain events occurring from May to August. Winter dew occurs throughout and often with fog rolling in from the sea in the mornings, sometimes fog also occurs in summer. The lowest temperatures in winter are around 10°C (but hardly any frost), and the highest temperatures in summer just above 25°C. See also climate diagram for SKs 8 Namaqualand Coastal Duneveld (Figure 5.39).

Important Taxa Succulent Shrubs: *Didelta carnosa* var. *tomentosa* (d), *Jordaaniella dubia* (d), *Manochlamys albicans* (d), *Othonna cylindrica* (d), *O. sedifolia* (d), *Tetragonia fruticosa* (d), *T. spicata* (d), *Zygophyllum cordifolium* (d), *Crassula subaphylla*, *Euphorbia brachiata*, *E. burmannii*, *Jordaaniella spongiosa*, *Salsola nollothensis*, *Stoeberia utilis*, *Tylecodon paniculatus*, *Zygophyllum morgsana*. Tall Shrubs: *Euclea racemosa* (d), *Chrysanthemoides monilifera* subsp. *pisifera*, *Ehretia rigida*, *Melianthus elongatus*, *Putterlickia pyracantha*. Low Shrubs: *Chrysanthemoides incana* (d), *Galenia fruticosa* (d), *Lebeckia halenbergensis* (d), *Nenax arenicola* (d), *Pteronia divaricata* (d), *Zygophyllum spinosum* (d), *Asparagus capensis* var. *litoralis*, *A. lignosus*, *Atriplex vestita* var. *appendiculata*, *Berkheya fruticosa*, *Capparis hereroensis*, *Chrysocoma ciliata*, *Eriocephalus racemosus* var. *affinis*, *Helichrysum hebelepis*, *Hermannia heterophylla*, *H. trifurca*, *Lebeckia cinerea*, *L. mucronata*, *Limeum africanum*, *Pteronia onobromoides*, *P. paniculata*, *Salvia lanceolata*, *Tripteris oppositifolia*. Woody Succulent Climber: *Pelargonium gibbosum*. Woody Climbers: *Asparagus fasciculatus*, *A. racemosus*, *Cissampelos capensis*, *Microloma sagittatum*. Semiparasitic Epiphytic Shrub: *Viscum capense*. Herbs: *Amellus alternifolius*, *Oncosiphon suffruticosum*. Succulent Herbs: *Conicosia pugioniformis* subsp. *alborosea*, *Psilocaulon dinteri*. Graminoids: *Cladoraphis cyperoides* (d), *Stipagrostis zeyheri* subsp. *macropus*.

Biogeographically Important Taxa ([NQ]Namaqualand endemic, [S]Southern distribution limit) Succulent Shrubs: *Amphibolia rupis-arcuatae*[S] (d), *Arctotis scullyi*[NQ], *Stoeberia beetzii*[NQ], *Vanzijlia annulata*[NQ]. Low Shrub: *Leucoptera nodosa*[NQ]. Succulent Herbs: *Crassula elegans* subsp. *elegans*[NQ], *Mesembryanthemum barklyi*[NQ]. Graminoid: *Eragrostis sabulosa* [NQ] (d).

Endemic Taxa Succulent Shrub: *Wooleya farinosa* (d). Herb: *Gazania* sp. nov. (*Mucina & Santos 7237/4* STEU).

Conservation Target 26%. None of the unit is conserved in statutory conservation areas, but an area between the Spoeg and Groen Rivers has been earmarked for a national park. Large areas were affected by diamond mining (about 8% of the area transformed) and prospecting. Kelp collection and vehicle tracks to the beach are also a disturbing factor in accessible places (much of the area is still out of limits due to occurrence of diamonds). *Acacia cyclops* locally invades the dunes. Erosion is generally very low.

Remark *Capparis hereroensis* has enormous old underground tubers, making it possible to survive moving dunes that periodically cover and uncover the plants. This species is known only from a few plants (< 20) between the Bitter and Swartlintjies Rivers and then they only occur in the Namib Desert in Namibia.

References Boucher & Le Roux (1993), A. le Roux (unpublished data).

SKs 9 Namaqualand Inland Duneveld

VT 31 Succulent Karoo (96%) (Acocks 1953). LR 57 Lowland Succulent Karoo (69%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Namaqualand Sandveld, where it occurs in two patches—one between Kotzesrus northwards to Groen River while another is located between Wallekraal and Hondeklipbaai. Altitude 60–280 m.

Vegetation & Landscape Features Coastal peneplain with mobile dunes. Vegetation is tall shrubland dominated by non-succulent shrubs (*Berkheya, Eriocephalus, Euclea, Gloveria, Lycium, Rhus, Tetragonia, Tripteris, Zygophyllum*) as well as some grasses (*Ehrharta*) and restioids (*Willdenowia*).

Geology & Soils Quaternary aeolian, deep, loose, red to yellowish sand, forming medium (1–3 m) to high (3–6 m) dunes. Ah land type covers almost two thirds of the area, while the rest is classified as Ai land type.

Climate Arid, winter-rainfall area with MAP only 104 mm, with almost all the rainfall from May to August. Dew occurs throughout the winter. Lowest temperatures in winter just below 10°C. Hardly any incidence of frost. The highest temperatures in summer 25–30°C. See also climate diagram for SKs 9 Namaqualand Inland Duneveld (Figure 5.39).

Important Taxa Succulent Shrubs: *Othonna cylindrica* (d), *Tetragonia fruticosa*, *Zygophyllum morgsana*. Tall Shrubs: *Diospyros ramulosa*, *Euclea racemosa*, *Nylandtia spinosa*, *Rhus longispina*, *R. undulata*. Low Shrubs: *Eriocephalus racemosus*

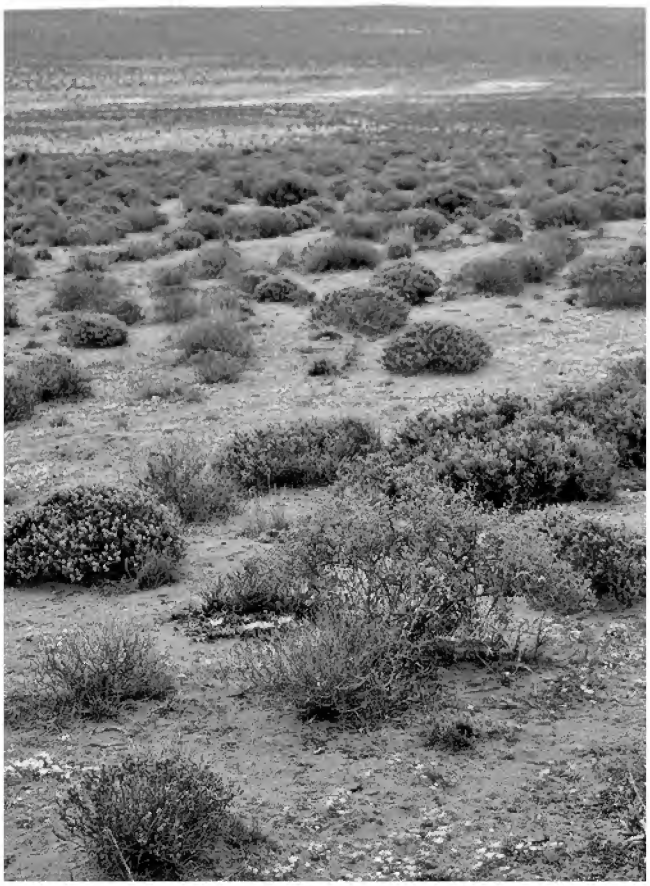

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Figure 5.48 SKs 9 Namaqualand Inland Duneveld: Succulent shrubland on deep sandy soils near Wallekraal in Namaqualand (Northern Cape).

var. *affinis* (d), *Helichrysum hebelepis* (d), *Berkheya fruticosa*, *Gloveria integrifolia*, *Hermannia trifurca*, *Lebeckia sericea*, *Monechma spartioides*, *Pharnaceum incanum*, *Pteronia paniculata*, *Salvia lanceolata*, *Selago pinguicula*, *Trichogyne ambigua*, *Tripteris oppositifolia*. Graminoids: *Willdenowia incurvata* (d), *Ehrharta barbinodis*, *E. calycina*, *Ficinia argyropa*.

Conservation Least threatened and none conserved in statutory conservation areas. Target 26%. No obvious transformation observed, although overgrazing and (animal) trampling can result in destabilising of the sandy substrate (on the whole erosion is still very low). Some areas are invaded by *Acacia cyclops*.

Reference A. le Roux (unpublished data).

SKs 10 Riethuis-Wallekraal Quartz Vygieveld

VT 31 Succulent Karoo (100%) (Acocks 1953). LR 57 Lowland Succulent Karoo (98%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Namaqualand, surrounds of Riethuis, Wallekraal and Soebatsfontein. Altitude 60–240 m.

Vegetation & Landscape Features Slightly undulating plains covered by white patches of quartz pavement covered with open-canopy dwarf-succulent shrubland with dominant local endemic species of *Jacobsenia*, *Monilaria* and *Dicrocaulon*.

Geology & Soils Shallow silty and skeletal soils, saline in part. In between with small-scale mosaics of level or sloping quartz patches. The underlying geology is gneiss of the Stalhoek Complex and Kamieskroon Gneiss. Ag land type is dominant, while Ae land type is only of subordinate importance.

Climate Winter-rainfall climate. MAP of 129 mm, with almost all the rainfall between May and August. The lowest temperatures in winter are 5–10°C. Frost occurs in winter, but it is very rare. The highest temperatures in the summer are 25–30°C. Frequent occurrence of fog (mainly in winter and spring) and dew representing an important source of water supply. See also climate diagram for SKs 10 Riethuis-Wallekraal Quartz Vygieveld (Figure 5.39).

Important Taxa ([O]Outside quartz patches) Succulent Shrubs: *Antimima watermeyeri* (d), *Cephalophyllum inaequale*[O] (d), *Drosanthemum pulverulentum*[O] (d), *Euphorbia hamata*, *Ruschia leucosperma*, *Salsola zeyheri*, *Senecio aloides*, *Tetragonia verrucosa*, *Zygophyllum cordifolium*. Low Shrubs: *Asparagus capensis* var. *capensis*, *Hirpicium alienatum*, *Pharnaceum elongatum*, *Pteronia ciliata*, *P. glabrata*, *Tripteris oppositifolia*[O]. Geophytic Herbs: *Bulbine sedifolia*, *Chlorophytum crassinerve*. Succulent Herbs: *Crassula columnaris* subsp. *prolifera*, *C. deceptor*, *Phyllobolus spinuliferus, Psilocaulon dinteri*. Graminoids: *Ehrharta barbinodis*[O], *Stipagrostis ciliata*[O], *S. obtusa*[O].

Biogeographically Important Taxa ([NQ]Namaqualand endemic, [R]Richtersveld endemic) Succulent Shrubs: *Aspazoma amplectens*[NQ] (d), *Meyerophytum meyeri*[NQ] (d), *Monilaria scutata* subsp. *obovata*[NQ] (d). Geophytic Herb: *Bulbine mesembryanthoides* subsp. *namaquensis*[R]. Succulent Herb: *Brownanthus corallinus*[NQ].

Endemic Taxa Succulent Shrubs: *Dicrocaulon ramulosum* (d), *D. spissum* (d), *Monilaria scutata* subsp. *scutata* (d), *Jacobsenia vaginata*, *Meyerophytum globosum*. Low Shrub: *Afrolimon namaquanum*. Succulent Herbs: *Conophytum auriflorum*, *C. concavum*, *C. obscurum* subsp. *vitreopapillum*, *Crassula susannae*.

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Figure 5.49 SKs 10 Riethuis-Wallekraal Quartz Vygieveld: Succulent shrubland dominated by *Meyerophytum meyeri* (Aizoaceae) in a quartz patch near Wallekraal (near Hondeklipbaai, Northern Cape).

Conservation Target 28%. About 25% of the unit is statutorily conserved in Namaqua National Park. Due to low suitability for grazing or other agricultural uses, the vegetation of this unique quartz vygieveld has not been transformed or disturbed to allow invasion of alien plants. Trampling and browsing caused severe damages to the vulnerable quartz-field vegetation. Erosion is very low.

References Schmiedel (2002a, b).

SKs 11 Namaqualand Arid Grassland

VT 31 Succulent Karoo (89%) (Acocks 1953). LR 57 Lowland Succulent Karoo (77%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Namaqualand, northwest of Soebatsfontein and patches south of Kliprand. Smaller patches also scattered within the Namaqualand Blomveld (these were not mapped due to small extent). Altitude 80–840 m.

Vegetation & Landscape Features Flat to slightly undulating plains covered with short grasslands dominated by *Stipagrostis ciliata* and *S. obtusa* and accompanied by few scattered dwarf shrubs. When overgrazed, the physiognomy of this grassland changes into open-canopy, dwarf shrubland.

Geology & Soils Quaternary aeolian, deep, coarse, loose, red sands overlying granitic-gneiss of the Stalhoek Complex as well as clastic sediments of the Knersvlakte Subgroup of the Vanrhynsdorp Group. Ag land type dominates the landscape and Ah and Ae land types make a small contribution.

Climate Winter-rainfall area with MAP of 131 mm, with almost all the rainfall between May and August. Due to the inland position of the unit, some frost days per year can be recorded. The lowest temperatures in winter range from 5–10°C, while the highest temperatures in summer are between 25°C and just higher than 30°C. See also climate diagram for SKs 11 Namaqualand Arid Grassland (Figure 5.39).

Important Taxa Succulent Shrubs: *Euphorbia decussata*, *Galenia sarcophylla*, *Hypertelis salsoloides*, *Lycium cinereum*, *Salsola zeyheri*, *Tetragonia fruticosa*, *Zygophyllum morgsana*. Low Shrubs: *Asparagus capensis* var. *capensis*, *Galenia fruticosa*, *G. meziana*, *Hermannia trifurca*, *Lebeckia halenbergensis*, *Limeum africanum*, *Tripteris sinuata*, *Zygophyllum microphyllum*, *Z. retrofractum*. Herb: *Gazania pectinata*. Geophytic Herb: *Drimia intricata*. Succulent Herb: *Conicosia pugioniformis* subsp. *alborosea*. Graminoids: *Stipagrostis ciliata* (d), *S. obtusa* (d), *Chaetobromus involucratus* subsp. *dregeanus*, *Cladoraphis spinosa*, *Ehrharta pusilla*, *Stipagrostis brevifolia*, *S. zeyheri* subsp. *macropus*.

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Figure 5.50 SKs 11 Namaqualand Arid Grassland: *Stipagrostis ciliata* grassland with an undescribed species of *Arctotis* (orange daisy), *Zaluzianskya affinis* (small white flowers) and *Dimorphotheca pluvialis* (white daisy) on deep red sands of ancient inland dunes near Soebatsfontein (Namaqua National Park, Northern Cape).

Biogeographically Important Taxon (Namaqualand endemic) Herb: *Kedrostis psammophylla*.

Conservation Target 26%. About 20% is statutorily conserved in Namaqua National Park, but none of the patches along the northeastern edges of the Knersvlakte enjoy any form of conservation. About 5% has been transformed by overgrazing. Erosion varies between low (50%), very low (30%) and moderate (20%).

Remark This grassland is structurally (and partly also floristically) related to the NKb 3 Bushmanland Arid Grassland, with the same dominant *Stipagrostis* species in deep red sands, although the grassland in Bushmanland receives summer rainfall. The occurrence of C_4-dominated grasslands within winter-rainfall regions remains unexplained, but the azonal character of the deep sandy soils (and possibly some features of their nutrient status) is a logical suspect.

Reference A. le Roux and L. Mucina (unpublished data).

SKs 12 Namaqualand Spinescent Grassland

VT 31 Succulent Karoo (67%) (Acocks 1953). LR 57 Lowland Succulent Karoo (72%) (Low & Rebelo 1996). BHU 77 Knersvlakte Vygieveld (72%) (Cowling & Heijnis 2001).

Distribution Western Cape Province: Namaqualand, a strip in the Knersvlakte from Lutzville and Koekenaap eastwards to north of Vanrhynsdorp. Altitude 60–340 m.

Vegetation & Landscape Features Level landscape covered with vegetation dominated by spinifex-like grass (*Cladoraphis spinosa*) and a few scattered emergent taller shrubs. The shrubs are both succulent (*Euphorbia, Ruschia, Othonna, Salsola, Zygophyllum*) and nonsucculent (*Hermannia, Justicia, Lebeckia, Lycium, Wiborgia*). Geophytes and annuals (especially obvious in wet years) occur in the shrub-grass matrix.

Geology & Soils Cenozoic aeolian, deep, coarse, unstructured, red, sandy soils with very low stone content, more or less neutral soil pH, low salinity and with no or very low carbonate content. Sand originated from the mouth of the palaeo-Orange River formerly located about east of the sand strip and it has been transported inland by the westerly winds. This ancient alluvium sediments are overlying Gariep Supergroup metapelites (mostly schist and phyllite) and some clastic sediments and metavolcanics (Namibian Erathem). Ae land type dominates and Ag land type plays only a subordinate role.

Climate Winter-rainfall climate with MAP of 151 mm, with almost all the rainfall between May and August. The lowest temperatures in winter are 5–10°C. Frost

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Figure 5.51 SKs 12 Namaqualand Spinescent Grassland: Mixed shrubland-grassland vegetation dominated by the spinifex-like grass *Cladoraphis spinosa*, with *Grielum humifusum* (bright yellow-flowered Neuradaceae) and various annual herbs (*Manulea, Wahlenbergia, Osteospermum, Zaluzianskya*) on deep red sands near the Varsch River, north of Vanrhynsdorp (Western Cape).

occurs in winter, but it is rare. The highest temperatures in summer are between 25°C and just higher than 30°C. See also climate diagram for SKs 12 Namaqualand Spinescent Grassland (Figure 5.39).

Important Taxa Succulent Shrubs: *Euphorbia burmannii* (d), *E. mauritanica* (d), *Zygophyllum morgsana* (d), *Antimima excedens*, *Aridaria noctiflora* subsp. *noctiflora*, *Augea capensis*, *Didelta spinosa*, *Othonna cylindrica*, *Prenia pallens* subsp. *lutea*, *Ruschia bipapillata*, *R. brevibracteata*, *Salsola namibica*, *S. zeyheri*, *Tetragonia fruticosa*, *T. spicata*. Tall Shrub: *Wiborgia obcordata*. Low Shrubs: *Lebeckia halenbergensis* (d), *Asparagus capensis* var. *capensis*, *Eriocephalus brevifolius*, *Galenia africana*, *Hermannia amoena*, *H. scordifolia*, *H. trifurca*, *Justicia cuneata* subsp. *latifolia*, *J. orchioides* subsp. *glabrata*, *Limeum africanum*, *Pteronia divaricata*, *Tripteris oppositifolia*, *Wiborgia sericea*. Woody Climbers: *Asparagus fasciculatus*, *A. retrofractus*, *Cissampelos capensis*, *Microloma sagittatum*. Herbaceous Climber: *Kedrostis capensis*. Herbs: *Dimorphotheca pluvialis* (d), *Foveolina tenella* (d), *Arctotheca calendula*, *Emex australis*, *Grielum grandiflorum*, *G. humifusum*, *Hebenstretia repens*, *Helichrysum micropoides*, *Heliophila arenaria*, *Indigofera alternans*, *Lyperia tristis*, *Nestlera biennis*, *Oncosiphon piluliferum*, *Osteospermum pinnatum*, *Phyllopodium phyllopodioides*, *Rumex cordatus*, *Silene clandestina*, *Sonderina tenuis*, *Wahlenbergia annularis*. Geophytic Herbs: *Boophone haemanthoides*, *Drimia altissima*, *Ornithoglossum viride*, *Oxalis flava*, *Trachyandra falcata*. Succulent Herb: *Apatesia helianthoides*. Graminoids: *Cladoraphis spinosa* (d), *Ehrharta brevifolia* (d), *Willdenowia incurvata* (d), *Chaetobromus involucratus* subsp. *dregeanus*, *Ehrharta calycina*, *Schismus barbatus*, *Stipagrostis ciliata*.

Biogeographically Important Taxa ([NQ]Namaqualand endemic, [K]Knersvlakte endemic, [N]Northern distribution limit, [S]Southern distribution limit) Succulent Shrub: *Othonna sparsiflora*[S]. Low Shrubs: *Aspalathus cuspidata*[NQ], *Nenax hirta* subsp. *calciphila*[N], *Otholobium incanum*[N]. Herbs: *Lebeckia sepiaria*[N], *Manulea altissima* subsp. *longifolia*[NQ], *Nemesia azurea*[S]. Geophytic Herb: *Lapeirousia simulans*[K]. Succulent Herb: *Crassula elegans* subsp. *elegans*[NQ]. Graminoid: *Ficinia bulbosa*[N].

Endemic Taxa Geophytic Herb: *Ornithogalum autumnulum*. Succulent Herbs: *Quaqua pulchra, Tridentea peculiaris.*

Conservation Least threatened. Target 26%. Only 4% statutorily conserved in Lutzville and Moedverloren Nature Reserves. The same percentage has been transformed and scattered *Acacia saligna* and *A. cyclops* might be a cause for concern in some areas. Erosion is very low (80%) and low (20%).

Remark This unit has some similarities to the SKs 13 Klawer Sandy Shrubland, but this grassland is most likely a more arid version of the tall shrubland, with shrubs becoming more prominent with increased rainfall.

References Schmiedel (2002a, b), Boucher (2003).

SKs 13 Klawer Sandy Shrubland

VT 31 Succulent Karoo (92%) (Acocks 1953). LR 57 Lowland Succulent Karoo (100%) (Low & Rebelo 1996). BHU 76 Klawer Vygieveld (100%) (Cowling & Heijnis 2001).

Distribution Western Cape Province: Lower Olifants River Valley in close surrounds of Klawer. Altitude 40–320 m.

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Figure 5.52 SKs 13 Klawer Sandy Shrubland: Deep white sands with sparse, tall shrubland dominated by *Montinia caryophyllacea* (Montiniaceae) and spinifex-like *Cladoraphis spinosa* (Poaceae) in the undergrowth accompanied by a species-rich spring display of annual and geophytic flora including various species of *Dimorphotheca, Oncosiphon, Osteospermum, Senecio, Ursinia, Zaluzianskya, Albuca* and *Lachenalia*.

Vegetation & Landscape Features Slightly undulating landscape and foothills covered with medium dense, tall shrubland with *Montinia caryophyllacea* and understorey with prominent sand-loving spinifex-like grass *Cladoraphis spinosa*.

Geology & Soils Well-drained, moderately deep to deep, yellow to red sands overlying Gariep Supergroup schists and phyllites as well as lesser sandstones, carbonates and metavolcanics. Some Table Mountain Group quartzites are also present. Occasionally heuweltjies occur as well. Ag land type is dominant, while the importance of Ae, Db and Fc land types is secondary.

Climate Winter-rainfall regime, with obvious peak from June to August. MAP reaches almost 200 mm (semidesert), but an additional contribution from regional precipitation (fog condensing on Gifberg escarpment) cannot be excluded. MAT 18–19°C and only 2 days of frost per year on average. See also climate diagram for SKs 13 Klawer Sandy Shrubland (Figure 5.39).

Important Taxa Succulent Shrubs: *Othonna cylindrica* (d), *Antimima dasyphylla*, *Delosperma crassum*, *Euphorbia mauritanica*, *E. tuberculata* var. *macowani*, *Manochlamys albicans*, *Prenia pallens* subsp. *lutea*, *Tetragonia fruticosa*, *Tylecodon paniculatus*, *T. wallichii* subsp. *wallichii*, *Zygophyllum morgsana*. Tall Shrubs: *Montinia caryophyllacea* (d), *Wiborgia obcordata*. Low Shrubs: *Lebeckia halenbergensis* (d), *Aizoon paniculatum*, *Aspalathus biflora* subsp. *biflora*, *Asparagus juniperoides*, *Eriocephalus brevifolius*, *Euryops namaquensis*, *Galenia africana*, *Hermannia cuneifolia*, *H. procumbens*, *Hoplophyllum spinosum*, *Justicia cuneata* subsp. *cuneata*, *J. orchioides* subsp. *glabrata*, *Limeum africanum*, *Pharnaceum incanum*, *Pteronia divaricata*, *P. glabrata*, *P. paniculata*, *Tripteris oppositifolia*, *Wiborgia fusca* subsp. *fusca*, *W. sericea*. Herbs: *Dimorphotheca pluvialis* (d), *Oncosiphon grandiflorum* (d), *Adenogramma glomerata*, *Amellus strigosus* subsp. *pseudoscabridus*, *Cotula microglossa*, *Dischisma spicatum*, *Emex australis*, *Felicia bergeriana*, *Foveolina tenella*, *Grielum humifusum*, *Helichrysum moeserianum*, *H. tinctum*, *Hemimeris racemosa*, *Leysera gnaphalodes*, *Nemesia bicornis*, *N. ligulata*, *Phyllopodium caespitosum*, *P. cephalophorum*, *Plantago cafra*, *Silene clandestina*, *Tripteris clandestina*, *Ursinia anthemoides* subsp. *versicolor*, *Wahlenbergia annularis*, *W. asperifolia*, *Zaluzianskya benthamiana*, *Z. villosa*. Geophytic Herbs: *Moraea collina* (d), *Ammocharis longifolia*, *Brunsvigia orientalis*, *Chlorophytum undulatum*, *Drimia intricata*, *Lachenalia ventricosa*, *Lapeirousia jacquinii*, *Moraea fugax*, *Ornithogalum maculatum*, *Oxalis annae*, *O. pes-caprae*, *O. purpurea*, *Trachyandra jacquiniana*, *T. scabra*, *Walleria gracilis*. Succulent Herbs: *Apatesia sabulosa*, *Conicosia pugioniformis* subsp. *pugioniformis*, *Tetragonia microptera*. Graminoids: *Cladoraphis spinosa* (d), *Stipa capensis* (d), *Chaetobromus involucratus* subsp. *dregeanus*, *Cynodon dactylon*, *Ehrharta barbinodis*, *E. brevifolia*, *E. calycina*, *Ficinia argyropa*, *Karroochloa schismoides*, *Pentaschistis capillaris*, *Tribolium pusillum*.

Biogeographically Important Taxa ([NQ]Namaqualand endemic, [K]Knersvlakte endemic, [S]Southern distribution limit, [W]Western distribution limit) Herbs: *Crotalaria effusa*[S], *Helichrysum marmarolepis*[NQ], *Steirodiscus capillaceus*[W]. Geophytic Herbs: *Ornithogalum pruinosum*[NQ], *Trachyandra zebrina*[S].

Endemic Taxa Herb: *Vellereophyton pulvinatum*. Geophytic Herb: *Haemanthus pubescens* subsp. *leipoldtii*.

Conservation Least threatened and none conserved in statutory conservation areas. Target 29%. About 6% transformed for cultivation or by road building. Erosion is moderate (65%) or very low (35%).

References Milton (1978), Boucher (2003).

Knersvlakte

SKk 1 Northern Knersvlakte Vygieveld

VT 31 Succulent Karoo (94%) (Acocks 1953). LR 57 Lowland Succulent Karoo (92%) (Low & Rebelo 1996).

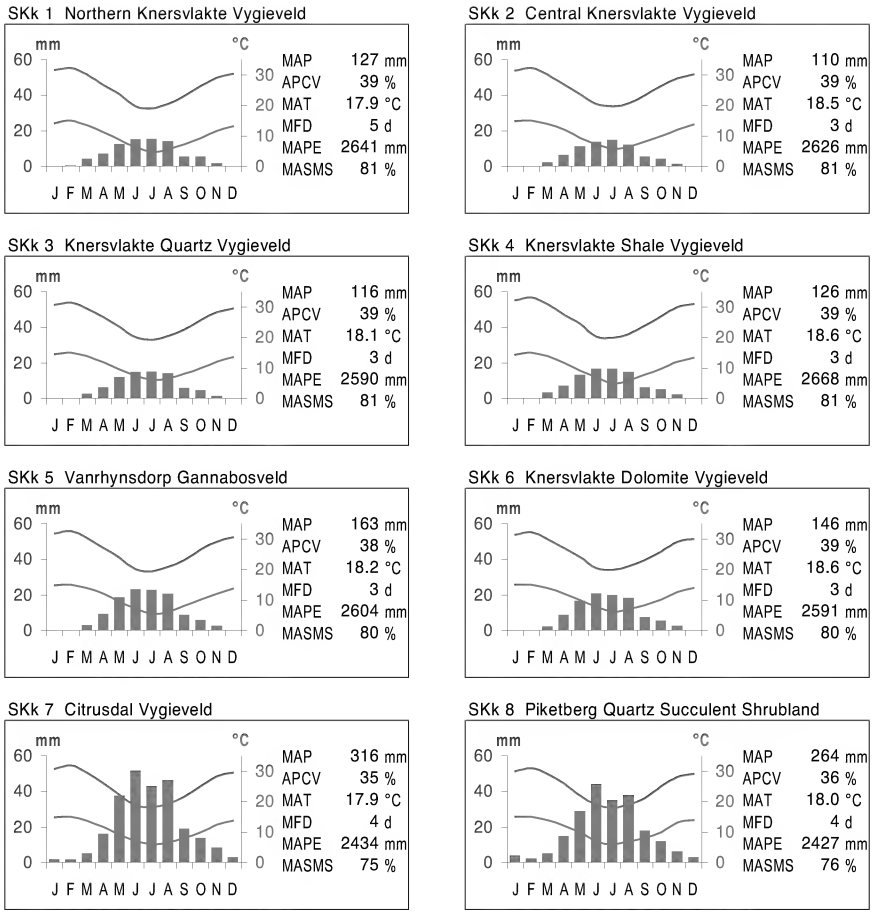

Figure 5.53 Climate diagrams of Knersvlakte Bioregion units. Blue bars show the median monthly precipitation. The upper and lower red lines show the mean daily maximum and minimum temperature respectively. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days (days when screen temperature was below 0°C); MAPE: Mean Annual Potential Evaporation; MASMS: Mean Annual Soil Moisture Stress (% of days when evaporative demand was more than double the soil moisture supply).

Distribution Western and Northern Cape Provinces: Knersvlakte (southern part of Namaqualand), situated roughly between Nuwerus and the escarpment in the east and the Sout River in the north. Only a small portion of this unit is found in the Northern Cape (in the upper valleys of the Kamdanie River and Krom River, west of Loeriesfontein). Altitude 200–800 m.

Vegetation & Landscape Features Slightly undulating landscape covered with open-canopy (10–30%) succulent shrubland. Heuweltjies occur in places and these are dominated by *Stoeberia frutescens* or *Lampranthus uniflorus*. Annuals and geophytes can determine the appearance of the vegetation in spring after good winter rains.

Geology & Soils Mostly Cenozoic alluvium and calcrete that overlies the mudstone, siltstone and sandstone of the Knersvlakte Subgroup (Vanrhynsdorp Group, Namibian Erathem) as well as gneiss of the Stalhoek Complex (Mokolian). Low stone content, soils acid to neutral, shallow to deep, where shallow bedrock or duripan crusts underly. Heuweltjies occur in places. Some 80% of the area falls within Ag land type, while Fc land type is the second most important one.

Climate Winter-rainfall climate with dry, hot summers and mild, rainy winters. MAP estimated to be 127 mm. The lowest temperatures in winter are 5–10°C, while the highest temperatures in summer are 30–35°C. Winters are mild, with rare occurrence of frost (on average 5 days per year). See also climate diagram for SKk 1 Northern Knersvlakte Vygieveld (Figure 5.53).

Important Taxa Succulent Shrubs: *Cephalophyllum framesii*, *C. parvibracteatum* (d), *Drosanthemum curtophyllum* (d), *D. pulverulentum* (d), *Leipoldtia calandra* (d), *Ruschia subsphaerica* (d), *Salsola zeyheri* (d), *Antimima watermeyeri*, *Augea capensis*, *Didelta carnosa* var. *carnosa*, *Galenia sarcophylla*, *Lampranthus uniflorus*, *Phyllobolus trichotomus*, *Ruschia lisabeliae*, *R. robusta*, *Salsola namibica*, *S. tuberculata*, *Tetragonia fruticosa*, *T. robusta* var. *psiloptera*, *Zygophyllum cordifolium*. Low Shrubs: *Asparagus capensis* var. *capensis*, *Galenia fruticosa*, *G. secunda*, *Lessertia depressa*, *Melolobium adenodes*, *Pteronia glabrata*, *P. intermedia*, *P. villosa*. Woody Climber: *Asparagus kraussianus*. Herbs: *Gazania lichtensteinii* (d), *Adenogramma glomerata*, *Amellus microglossus*, *Cotula microglossa*, *Diascia pachyceras*, *Felicia bergeriana*, *Heliophila variabilis*, *Lotononis parviflora*, *Lyperia tristis*, *Manulea cheiranthus*, *M. gariepina*, *Oncosiphon suffruticosum*, *Pelargonium minimum*, *Pharnaceum croceum*, *Rhynchopsidium pumilum*, *Tripteris breviradiata*, *Ursinia nana*, *Zaluzianskya benthamiana*, *Z. villosa*. Geophytic Herbs: *Cyanella hyacinthoides*, *Drimia intricata*, *Eriospermum paradoxum*, *Freesia viridis*, *Moraea ciliata*, *M. pallida*, *Ornithoglossum viride*, *Oxalis annae*, *O. obtusa*, *O. purpurea*, *Trachyandra jacquiniana*. Succulent Herbs: *Brownanthus vaginatus*, *Notechidnopsis tessellata*, *Phyllobolus nitidus*, *P. spinuliferus*, *Psilocaulon junceum*, *Quaqua acutiloba*.

Biogeographically Important Taxa ([NQ]Namaqualand endemic, [K]Knersvlakte endemic) Succulent Shrubs: *Drosanthemum schoenlandianum*[K], *Hallianthus planus*[NQ], *Malephora purpureocrocea*[NQ], *Stoeberia frutescens*[NQ]. Succulent Herb: *Tromotriche revoluta*[K].

Endemic Taxon Geophytic Herb: *Lachenalia framesii*.

Conservation Least threatened. Target 28%. None conserved in statutory conservation areas. Largely nontransformed, but stretches can be severely disturbed by the alien *Atriplex lindleyi* subsp. *inflata*, in places dominating the vegetation cover. Erosion is mainly low (78%) or very low (11%).

References Schmiedel (2002a, b).

SKk 2 Central Knersvlakte Vygieveld

VT 31 Succulent Karoo (100%) (Acocks 1953). LR 57 Lowland Succulent Karoo (90%) (Low & Rebelo 1996). BHU 77 Knersvlakte Vygieveld (83%) (Cowling & Heijnis 2001).

Distribution Western Cape Province: Knersvlakte (southern part of Namaqualand), along the upper courses of the Salt River and the Groot-Graafwater River north of Vanrhynsdorp. About half of the area is found at altitudes of 100–200 m and most of the rest at 200–300 m.

Vegetation & Landscape Features Slightly undulating landscape covered with low succulent shrubland with low canopy cover (5–30%). The dominant shrub genera include *Ruschia, Drosanthemum* and *Leipoldtia*.

Geology & Soils Underlain by the clastic sediments of the Vanrhynsdorp Group (particularly by the Knersvlakte Subgroup, Namibian Erathem) and partly covered by Cenozoic superficial deposits and some Gariep Supergroup schists. Soils are shallow to moderately deep, with low salinity and sometimes deep, coarse and unstructured red, aeolian, sandy soils with very low skeletal content. Half of the area is classified as Fc land type, while Ia and Ah land types cover about one quarter of the area each.

Climate Winter-rainfall climate with dry, hot summers and mild, rainy winters. MAP of 110 mm, fog and dew occasionally sup-

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Figure 5.54 SKk 2 Central Knersvlakte Vygieveld: *Drosanthemum pulverulentum* dominant in dwarf succulent shrubland on shale-derived soils of the central Knersvlakte near Vanrhynsdorp (Western Cape).

plementing the water supply. Lowest temperatures in winter 5–10°C. The highest temperatures in summer 30–35°C. Winters are mild, with rare occurrence of frost (on average 3 days per year). See also climate diagram for SKk 2 Central Knersvlakte Vygieveld (Figure 5.53).

Important Taxa Succulent Shrubs: *Drosanthemum pulverulentum* (d), *Leipoldtia schultzei* (d), *Ruschia robusta* (d), *Aridaria brevicarpa*, *Augea capensis*, *Drosanthemum curtophyllum*, *Euphorbia burmannii*, *Salsola zeyheri*. Low Shrubs: *Asparagus capensis* var. *capensis*, *Galenia africana*, *G. fruticosa*, *Zygophyllum retrofractum*. Woody Climber: *Asparagus kraussianus*. Herb: *Galenia papulosa*. Geophytic Herb: *Drimia altissima*. Succulent Herbs: *Conicosia pugioniformis* subsp. *alborosea*, *Phyllobolus nitidus*, *P. spinuliferus*. Graminoids: *Hordeum capense*, *Pentaschistis airoides*.

Biogeographically Important Taxon (Knersvlakte endemic) Succulent Shrub: *Drosanthemum schoenlandianum*.

Endemic Taxon Succulent Shrub: *Tylecodon nolteei*.

Conservation Least threatened. Target 28%. None conserved in statutory conservation areas. Mainly not transformed, but some areas are severely disturbed by the alien *Atriplex lindleyi* subsp. *inflata*. Erosion is low (74%) or moderate (15%).

Remark In contrast to the SKk 1 Northern Knersvlakte Vygieveld, this unit is characterised by alluvial sandy soils, increased abundance of graminoid species and taller (*Aridaria brevicarpa*, *Ruschia robusta*) as well as cushion-forming leaf-succulents (*Ruschia versicolor*).

References Schmiedel (2002a, b).

SKk 3 Knersvlakte Quartz Vygieveld

VT 31 Succulent Karoo (95%) (Acocks 1953). LR 57 Lowland Succulent Karoo (97%) (Low & Rebelo 1996). BHU 77 Knersvlakte Vygieveld (62%) (Cowling & Heijnis 2001).

Distribution Western Cape Province: Knersvlakte (southern part of Namaqualand), from Bitterfontein southwards to just south of Klawer, with the main centre north and northwest of Vanrhynsdorp. Altitude 40–460 m (with most of the area 100–280 m).

Vegetation & Landscape Features Slightly undulating landscape with slopes and broad ridges covered by prominent though very patchy white layer of quartzite. The succulent shrublands supported by this relatively young (Tertiary) plain are mostly dwarf, with a high proportion of compact and subterranean vygies (Aizoaceae), often imitating their surroundings. This is probably the most extensive area of 'living stones' in the world. The mosaic of floristically and ecologically distinct quartz vygieveld communities and the matrix of low succulent shrublands, with *Ruschia* and *Drosanthemum* as the most prominent structure-determining genera, are very intricate and small-scale in places. Spectacular flower displays of both perennial and annual species flowering *en masse* and simultaneously are a common sight after good winter rain. The increased occurrence of indigenous *Caulipsolon rapaceum, Drosanthemum hispidum, Malephora purpureo-crocea*, *Mesembryanthemum guerichianum* as well as of the alien *Atriplex lindleyi* subsp. *inflata* is a good indicator of local veld disturbance.

Geology & Soils Clastic sediments of the Vanrhynsdorp Group and some Gariep Supergroup schists supporting loamy-sandy shallow to moderately deep, slightly alkaline soils, low to high stone (especially quartz) content. Fc and Fb are land types of equal importance (both covering about a third of the area), followed by Ag land type.

Climate Winter-rainfall climate with dry, hot summers and mild, rainy winters. MAP 116 mm. Fog and dew occasionally supplementing the water supply. The lowest temperatures in winter 5–10°C. The highest temperatures in summer 30–35°C. Winters are mild, with rare occurrence of frost (on average 3 days per year). See also climate diagram for SKk 3 Knersvlakte Quartz Vygieveld (Figure 5.53).

Important Taxa Succulent Shrubs: *Didelta carnosa* var. *carnosa* (d), *Drosanthemum diversifolium* (d), *Ruschia burtoniae* (d), *Antimima watermeyeri*, *Euphorbia mauritanica*, *E. muricata*, *Galenia sarcophylla*, *Pelargonium crithmifolium*, *Prenia tetragona*, *Ruschia cymosa*, *R. leucosperma*, *R. patulifolia*, *Salsola aphylla*, *S. namibica*, *Senecio aloides*, *Tetragonia verrucosa*, *Tylecodon reticulatus*, *T. ventricosus*, *Zygophyllum cordifolium*. Low Shrubs: *Berkheya fruticosa*, *Galenia fruticosa*, *Hirpicium alienatum*, *Pteronia ciliata*, *P. heterocarpa*, *Tripteris sinuata*, *Zygophyllum retrofractum*. Semiparasitic Shrub: *Thesium lineatum*. Herbs: *Amellus microglossus* (d), *Dimorphotheca sinuata* (d), *Oncosiphon suffruticosum* (d), *Lasiopogon glomerulatus*, *Nemesia anisocarpa*, *Oncosiphon piluliferum*, *Osteospermum pinnatum*, *Rhynchopsidium pumilum*. Geophytic Herbs: *Drimia intricata* (d), *Oxalis annae* (d), *O. obtusa*, *O. pes-caprae*, *O. purpurea*. Succulent Herbs: *Tetragonia echi-*

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Figure 5.55 SKk 3 Knersvlakte Quartz Vygieveld: Dwarf succulent shrubland dominated by endemic *Dactylopsis digitata* (Aizoaceae) on the Farm Quaggaskop near Salt River, northwest of Vanrhynsdorp (Western Cape).

nata (d), *Aloe variegata*, *Crassula columnaris* subsp. *prolifera*, *C. deceptor*, *C. expansa* subsp. *expansa*, *C. muscosa*, *C. subaphylla*, *Mesembryanthemum fastigiatum*, *M. nodiflorum*, *Psilocaulon dinteri*. Graminoids: *Ehrharta delicatula* (d), *Karroochloa tenella*, *Schismus barbatus*.

Biogeographically Important Taxa ([NQ]Namaqualand endemic, [K]Knersvlakte endemic) Succulent Shrubs: *Malephora purpureo-crocea*[NQ] (d), *Euphorbia schoenlandii*[K], *Tylecodon pearsonii*[NQ]. Succulent Herbs: *Brownanthus corallinus*[NQ] (d), *Crassula elegans* subsp. *elegans*[NQ], *C. expansa* subsp. *pyrifolia*[NQ].

Endemic Taxa Succulent Shrubs: *Argyroderma crateriforme* (d), *A. delaetii* (d), *A. fissum* (d), *A. patens* (d), *A. pearsonii* (d), *Cephalophyllum spissum* (d), *Dactylopsis digitata* (d), *Dicrocaulon brevifolium* (d), *D. nodosum* (d), *Dicrocaulon* sp. nov. ('*longifolium*') (d), *Dicrocaulon* sp. nov. ('*pseudonodosum*') (d), *Monilaria chrysoleuca* (d), *M. moniliformis* (d), *M. pisiformis* (d), *Oophytum nanum* (d), *O. oviforme* (d), *Afrolimon teretifolium*, *Antimima dualis*, *Argyroderma congregatum*, *A. framesii* subsp. *framesii*, *A. framesii* subsp. *hallii*, *A. ringens*, *A. subalbum*, *A. testiculare*, *Cephalophyllum staminodiosum*, *Dactylopsis littlewoodii*, *Dicrocaulon grandiflorum*, *D. humile*, *D. microstigma*, *Dicrocaulon* sp. nov. ('*nanum*'), *D.* sp. nov. ('*neglectum*'), *Dicrocaulon sp.* nov. ('*prostratum*'), *Diplosoma luckhoffii*, *Ruschia firma*, *Salsola* sp. nov. ('*quartzicola*') (*Schmiedel 93110* HBG, *Mucina 160601/9* STEU), *Sarcocornia xerophila*, *Tylecodon occultans*, *T. peculiaris*, *T. pygmaeus*, *Zygophyllum teretifolium*. Low Shrub: *Pentzia peduncularis*. Geophytic Herbs: *Bulbine wiesei*, *Lachenalia barkeriana*, *Moraea deserticola*, *Ornithogalum knersvlaktense*, *Pelargonium caroli-henrici*, *P. quarciticola*, *Romulea maculata*. Succulent Herbs: *Conophytum acutum*, *C. calculus* subsp. *calculus*, *C. minutum* var. *minutum*, *C. minutum* var. *pearsonii*, *C. subfenestratum*, *Othonna intermedia*, *Phyllobolus abbreviatus*.

Conservation Least threatened, although in places still utilised for grazing by goats. Target 28%. About 5% is statutorily conserved in Moedverloren Nature Reserve. The area is disturbed by prospecting for diamonds (ceased) in the past and gypsum mining, leaving behind mine spoil heaps in places. Alien plants are not a big problem, although *Atriplex lindleyi* subsp. *inflata* is invading where saline quartz fields have been disturbed by trampling or off-road driving. Erosion is low (75%) or very low (20%).

Remark 1 The white quartz debris originates from weathered quartz veins which are embedded within the bedrock matrix. The quartz veins weather and are spread downhill by alluvial transport. Quartz fields in the arid regions of southern Africa represent edaphically defined special habitats, which house distinct vegetation units. In different regions, the quartz fields are inhabited by similar plant growth forms of distantly related lineages (compare SKv 10 Little Karoo Quartz Vygieveld and SKs 10 Riethuis-Wallekraal Quartz Vygieveld).

Remark 2 This vegetation unit carries one of the largest local densities of endemic plants, counting more than 60 species and three genera (*Argyroderma, Dactylopsis* and *Oophytum*: all Aizoaceae). The genera *Dicrocaulon*, *Monilaria* (Aizoaceae) and *Tylecodon* (Crassulaceae) score high numbers of endemic species here—a phenomenon shared with other Namaqualand quartz vygievelds.

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Figure 5.56 SKk 3 Knersvlakte Quartz Vygieveld: Spring flower aspect dominated by *Malephora purpureo-caerulea* (Aizoaceae) and the yellow daisies *Didelta carnosa* var. *carnosa* and *Rhynchopsidum pumilum*, south of Bitterfontein (Western Cape).

References Van Jaarsveld (1998b), Schmiedel & Jürgens (1999), Schmiedel (2002a, b), Ellis et al. (2006).

SKk 4 Knersvlakte Shale Vygieveld

VT 31 Succulent Karoo (93%) (Acocks 1953). LR 57 Lowland Succulent Karoo (96%) (Low & Rebelo 1996). BHU 77 Knersvlakte Vygieveld (93%) (Cowling & Heijnis 2001).

Distribution Western Cape Province: Knersvlakte (southern part of Namaqualand), at the western foot of the Bokkeveld Escarpment near Vanrhynsdorp. Altitude 160–540 m.

Vegetation & Landscape Features Low (10–20% of canopy cover) shrubland formed by mat-forming and cushion-forming shrubs, mainly with succulent leaves and high incidence of spinescence. *Ruschia* and *Salsola* are the major dominants.

Geology & Soils Shale bands of the Knersvlakte Subgroup (Vanrhynsdorp Group, Namibian Erathem), on level plains or hilltops and moderate to steep slopes covered by shallow soils, moderately acid to slightly alkaline, high stone content. Almost the entire area is classified as Fc land type.

Climate Winter-rainfall climate with dry, hot summers and mild, rainy winters. MAP 126 mm, with almost all the rainfall between May and August. The lowest temperatures in winter 5–10°C, highest temperatures in summer 30–35°C. Winters are mild, with rare occurrence of frost (on average 3 days per year). See also climate diagram for SKk 4 Knersvlakte Shale Vygieveld (Figure 5.53).

Important Taxa Succulent Shrubs: *Arenifera stylosa* (d), *Caulopsilon rapaceum* (d), *Ruschia spinosa* (d), *Salsola zeyheri* (d), *Augea capensis*, *Cheiridopsis namaquensis*, *Lampranthus uniflorus*, *Salsola aphylla*, *S. namibica*, *Tetragonia fruticosa*, *Tylecodon wallichii* subsp. *wallichii*, *Zygophyllum foetidum*. Low Shrubs: *Asparagus capensis* var. *capensis*, *Atriplex vestita* var. *appendiculata*, *Eriocephalus ericoides*, *Galenia fruticosa*, *Hirpicium alienatum*, *Pteronia ciliata*, *Tripteris sinuata*. Woody Climber: *Asparagus kraussianus*. Herbs: *Dimorphotheca sinuata* (d), *Gorteria diffusa* subsp. *diffusa* (d), *Oncosiphon suffrutico-*

sum (d), *Osteospermum pinnatum* (d), *Amellus microglossus*, *Emex australis*, *Jamesbrittenia glutinosa*, *Lasiopogon glomerulatus*, *Lepidium africanum*, *Sisymbrium capense*. Geophytic Herbs: *Drimia intricata*, *Gethyllis lata* subsp. *lata*, *G. linearis*, *Oxalis pes-caprae*. Succulent Herbs: *Brownanthus vaginatus* (d), *Phyllobolus nitidus*, *Psilocaulon dinteri*, *P. junceum*, *Tetragonia microptera*. Graminoids: *Ehrharta delicatula*, *E. longiflora*, *Karroochloa tenella*.

Biogeographically Important Taxa ([NQ]Namaqualand endemic, [K]Knersvlakte endemic) Succulent Shrub: *Malephora purpureo-crocea*[NQ]. Herb: *Lasiopogon debilis*[K]. Succulent Herb: *Tromotriche revoluta*[K].

Endemic Taxon Succulent Shrub: *Tylecodon suffultus*.

Conservation Target 28%. None of the unit is conserved in statutory conservation areas. Local overgrazing and high erosion pressure (90%) can be seen as threats in some places, otherwise no visible signs of transformation. *Atriplex lindleyi* subsp. *inflata* is the most common invasive alien.

Remark This unit houses a number of Karoo elements typical of the summer-rainfall region and shows traits of transition between the summer-rainfall and winter-rainfall regions.

References Schmiedel (2002a, b).

SKk 5 Vanrhynsdorp Gannabosveld

VT 31 Succulent Karoo (92%) (Acocks 1953). LR 57 Lowland Succulent Karoo (95%) (Low & Rebelo 1996). BHU 77 Knersvlakte Vygieveld (79%) (Cowling & Heijnis 2001).

Distribution Western Cape Province: Namaqualand, southern Knersvlakte between Vredendal and Vanrhynsdorp at the foot of the Matsikamma and Gifberg Mountains as well as northeast of Vanrhynsdorp. About half of the area lies at 100–200 m and most of the rest at 200–300 m.

Vegetation & Landscape Features Mainly flat or only slightly undulating landscape supporting succulent shrubland dominated by *Salsola* (over large stretches), *Drosanthemum, Ruschia* and some disturbance indicators such as (mainly) short-lived Aizoaceae, including representatives of the genera *Galenia, Psilocaulon, Caulipsolon* and *Mesembryanthemum*. In the south, the shale plains can acquire a grassland appearance through seasonal dominance of *Bromus pectinatus* and *Stipa capensis*. Spectacular annual and geophyte flora can appear in spring after good winter rains.

Geology & Soils The greater part of this area is underlain by schists, phyllite and sandstones of the Gariep Supergroup, which outcrop when they are not covered by recent superficial deposits of alluvium and duripan crusts (calcrete). Soils are sandy-loamy, moderately deep, slightly acid to alkaline, with high skeletal content. More than half of the area is classified as Ag land type, followed by Fc land type, with Db and Ae land types only of minor importance.

Climate Winter-rainfall climate with dry, hot summers and mild, rainy winters. MAP of 163 mm is considerably higher than in the other parts of the Knersvlakte due to the orographic effects of the neighbouring Matsikamma and Gifberg Mountains and the Escarpment. Almost all the rainfall occurs between April and August. The lowest temperatures in winter 5–10°C; the highest temperatures in summer 30–35°C. Winters are mild, with rare occurrence of frost (on average 3 days per year). See also climate diagram for SKk 5 Vanrhynsdorp Gannabosveld (Figure 5.53).

Important Taxa Succulent Shrubs: *Caulipsolon rapaceum* (d), *Drosanthemum deciduum* (d), *D. hispidum* (d), *Euphorbia mauritanica* (d), *Salsola namibica* (d), *S. zeyheri* (d), *Adromischus sphenophyllus*, *Antimima dasyphylla*, *Aridaria brevicarpa*, *A. noctiflora* subsp. *noctiflora*, *Delosperma crassum*, *Drosanthemum latipetalum*, *Euphorbia aspericaulis*, *Lampranthus uniflorus*, *Manochlamys albicans*, *Ruschia fugitans*, *Tetragonia hirsuta*, *T. sarcophylla*, *Tylecodon reticulatus*, *T. ventricosus*, *Zygophyllum cordifolium*. Low Shrubs: *Galenia fruticosa* (d), *Asparagus capensis* var. *capensis*, *A. suaveolens*, *Chrysocoma longifolia*, *Eriocephalus microphyllus* var. *pubescens*, *Galenia africana*, *Hermannia cuneifolia*, *Pteronia paniculata*, *Selago albida*, *Tripteris sinuata*. Herbs: *Gazania lichtensteinii* (d), *Foveolina dichotoma* (d), *Oncosiphon suffruticosum* (d), *Tribulus terrestris* (d), *Adenogramma glomerata*, *Amellus microglossus*, *Arctotis hirsuta*, *Cotula microglossa*, *Cromidon corrigioloides*, *Dimorphotheca sinuata*, *Felicia namaquana*, *F. tenella*, *Gazania krebsiana* subsp. *arctotoides*, *Gorteria diffusa* subsp. *diffusa*, *Grielum humifusum*, *Heliophila pendula*, *Nestlera biennis*, *Osteospermum pinnatum*, *Plantago cafra*, *Rhynchopsidium pumilum*, *Tripteris microcarpa*. Geophytic Herbs: *Babiana minuta*, *B. sambucina* var. *longibracteata*, *Cyanella orchidiformis*, *Dipcadi crispum*, *Lapeirousia exilis*, *Massonia echinata*, *Moraea galaxia*, *M. miniata*, *Oxalis annae*, *O. compressa*, *O. pes-caprae*, *O. purpurea*, *Sparaxis galeata*, *Strumaria unguiculata*, *Trachyandra falcata*, *T. jacquiniana*, *T. scabra*. Succulent Herbs: *Psilocaulon junceum* (d), *Apatesia helianthoides*, *A. sabulosa*, *Phyllobolus nitidus*, *Psilocaulon leptarthron*. Graminoids: *Stipa capensis* (d), *Bromus pectinatus, Ehrharta ramosa* subsp.

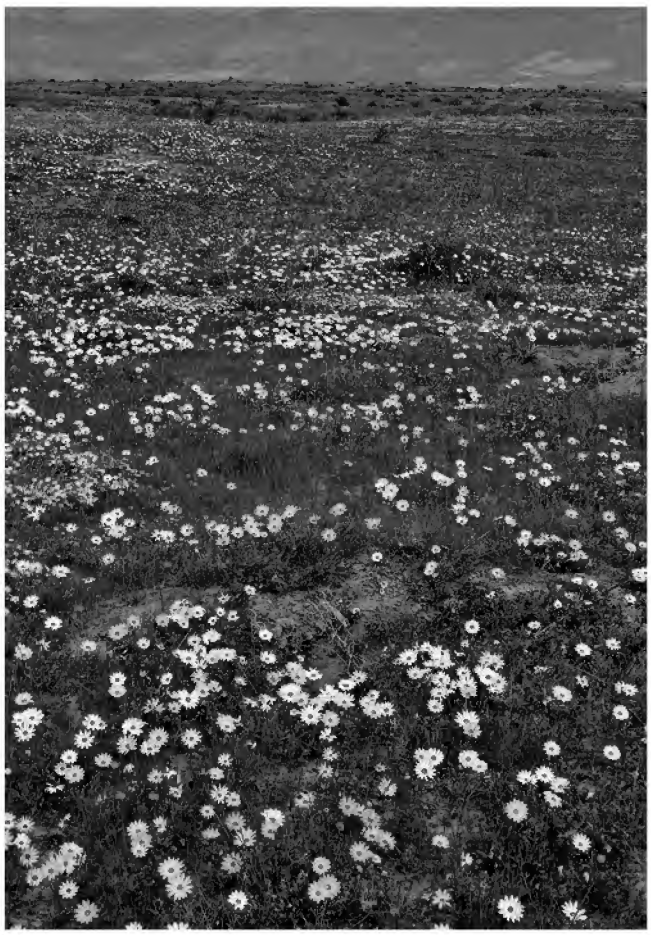

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Figure 5.57 SKk 5 Vanrhynsdorp Gannabosveld: Flower-rich spring aspect on shaly soils of the Knersvlakte south of Vanrhynsdorp (Western Cape). The dominant plants include *Osteospermum pinnatum* (pink), local endemic vygie *Caulipsolon rapaceum* (white) and *Foveolina dichotoma* (yellow daisy).

aphylla, *Enneapogon desvauxii*, *Ficinia argyropa*, *Karroochloa tenella*, *Pentaschistis patula*, *Stipagrostis ciliata*, *S. zeyheri* subsp. *macropus*, *Tribolium pusillum*.

Biogeographically Important Taxa ([NQ]Namaqualand endemic, [K]Knersvlakte endemic) Succulent Shrubs: *Drosanthemum schoenlandianum*[K], *Malephora purpureo-crocea*[NQ]. Herbs: *Manulea altissima* subsp. *longifolia*[NQ], *Ursinia pygmaea*[K]. Geophytic Herbs: *Babiana salteri*[K], *Lapeirousia simulans*[K], *Oxalis copiosa*[NQ].

Endemic Taxa Succulent Shrub: *Euphorbia fasciculata*. Geophytic Herbs: *Eriospermum eriophorum*, *Ornithogalum diluculum*. Succulent Herb: *Brownanthus glareicola*. Herb: *Cotula pedunculata*.

Conservation Vulnerable region due to transformation pressure. None of the unit is conserved in statutory conservation areas. Target 28%. So far 20% transformed into cultivated land and open-cast gypsum mining. Rehabilitation after open-cast mining remains minimal due to lack of little viable topsoil to cover the rehabilitated fields. Aliens (*Atriplex, Bromus*) have invaded large patches of vegetation. Increased cover of *Stipa capensis* (despite the name still unclear whether of indigenous or alien origin) diminishes grazing potential for sheep (due to damage to wool by caryopses). Erosion is moderate (71%) to high (18%).

References Greeff (1987), Steinschen et al. (1996), Schmiedel (2002a, b), Boucher (2003).

SKk 6 Knersvlakte Dolomite Vygieveld

VT 31 Succulent Karoo (100%) (Acocks 1953). LR 57 Lowland Succulent Karoo (100%) (Low & Rebelo 1996). BHU 76 Klawer Vygieveld (98%) (Cowling & Heijnis 2001).

Distribution Western Cape Province: Namaqualand, Knersvlakte between Vanrhynsdorp and the Farm Aties along the Troe-Troe River. Altitude 40–180 m

Vegetation & Landscape Features Sparse, succulent shrubland (canopy cover 10–30%) dominated by erect shrubs lower than 0.3 m with succulent leaves. In overgrazed habitats annual weeds and spiny, nonsucculent dwarf shrubs can become dominant.

Geology & Soils Metasediments of the Namibian Gariep Supergroup, in particular, on the dolomite-rich units. Soils are moderately deep, with high content of soil skeleton, typically slightly alkaline with high carbonate content. Entire area is classified as Ag land type.

Climate Winter-rainfall climate with dry, hot summers and mild, rainy winters. MAP of 164 mm is considerably higher than in the other parts of the Knersvlakte due to the orographic effects of the adjacent escarpment. Almost all the rainfall occurs between April and August. The lowest temperatures in winter 5–10°C, highest temperatures in summer 30–35°C. Winters are mild, with rare occurrence of frost (on average 3 days per year). See also climate diagram for SKk 6 Knersvlakte Dolomite Vygieveld (Figure 5.53).

Important Taxa Succulent Shrubs: *Drosanthemum pulverulentum* (d), *Salsola zeyheri* (d), *Zygophyllum divaricatum*. Low Shrubs: *Hermannia cuneifolia* (d), *Melolobium candicans* (d), *Asparagus capensis* var. *capensis*, *Galenia fruticosa*. Geophytic Herb: *Sparaxis galeata*. Graminoids: *Stipa capensis* (d), *Tribolium echinatum*.

Biogeographically Important Taxon (Knersvlakte endemic) Succulent Shrub: *Euphorbia schoenlandii*.

Conservation Least threatened. Target 28%. None of the unit is conserved in statutory conservation areas. Local invasion of aliens (*Atriplex lindleyi* subsp. *inflata*) can diminish the utilisation potential in overgrazed areas. Erosion is moderate.

References Schmiedel (2002a, b).

SKk 7 Citrusdal Vygieveld

VT 69 Macchia (Fynbos) (60%) (Acocks 1953). Mosaic of Dry Mountain Fynbos & Karroid Shrublands (35%), Mesic Mountain Fynbos (16%) (Moll & Bossi 1984). LR 64 Mountain Fynbos (93%) (Low & Rebelo 1996). BHU 47 Cederberg Mountain Fynbos Complex (56%) (Cowling & Heijnis 2001).

Distribution Western Cape Province: The unit encompasses several patches situated on the broad bottom of the Olifants River valley spanning surrounds of Citrusdal in the south, Clanwilliam, and Klawer in the north. Due to floristic and geologic reasons we incorporate into this unit also narrow shale bands crossing the low and mid-slopes of the valley. Altitude 180–700 m.

Vegetation & Landscape Features Broad, slightly sloping mountain flanks as well as ridges of low hillocks emerging from the bottom of the broad valley between mountain ranges. Covered with mainly succulent shrublands, medium to tall in height (often dominated by *Euphorbia mauritanica* and vygies) and with spectacular displays (in precipitation-rich years) of spring annual and geophyte flora. Vegetation of low-lying shale bands embedded within the hard sandstones of the Nardouw series of the Olifants River Valley supports this vegetation type as well.

Geology & Soils Dominated by shale and quartzite of the Cape Supergroup (most important being the Ceres Subgroup of the Bokkeveld Group and the Nardouw and Peninsula Subgroups of the Table Mountain Group) supporting sandy and sandy-loamy,

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Figure 5.58 SKk 7 Citrusdal Vygieveld: Succulent shrubland with dominant *Euphorbia mauritanica* (in foreground) and numerous heuweltjies dotting the shale slopes near Clanwilliam (Western Cape).

moderately deep soils. The area is a mosaic of five almost equally important land types: Fc, Ib, Fb, Db and Ia.

Climate Winter-rainfall climate—the modelled MAP of 316 mm is the highest among the Knersvlakte vegetation units, but one can accept real values to be lower, apparently due to pronounced rainshadow effect. The mountains of the Olifants River in the south and Swartberg and Uitkomsberge in the north catch the scanty precipitation brought in by northwesterly winds and prevent penetration of the ocean-borne fog into the Olifants River Valley. MAT is around 18°C. Winters are mild, while summers are relatively hot. The incidence of frost is within the Knersvlakte norm (3–5 days per year). See also climate diagram for SKk 7 Citrusdal Vygieveld (Figure 5.53).

Important Taxa Succulent Shrubs: *Euphorbia mauritanica* (d), *Aloe comosa, Cotyledon paniculata, Euphorbia burmannii, Ruschia decurvans*. Tall Shrubs: *Didelta spinosa* (d), *Montinia caryophyllacea* (d), *Berkheya fruticosa*, *Nylandtia spinosa*, *Rhus undulata*. Low Shrubs: *Galenia africana* (d), *Diosma passerinoides*, *Elytropappus rhinocerotis*, *Tetragonia hirsuta*. Herbs: *Dimorphotheca pluvialis* (d), *Ursinia anthemoides* subsp. *versicolor* (d), *U cakilefolia* (d), *Heliophila coronopifolia*, *Leysera tenella*, *Senecio elegans*, *Tetragonia rosea*. Geophytic Herbs: *Albuca maxima* (d), *Massonia depressa* (d), *Bulbinella graminifolia, Cyanella alba, C. hyacinthoides*, *C. lutea*, *Gladiolus recurvus*, *Haemanthus amarylloides* subsp. *amarylloides*, *Melasphaerula ramosa*, *Moraea villosa*, *Oxalis obtusa*, *O. purpurea, Trachyandra dissecta, Valtheimia capensis*. Succulent Herbs: *Dorotheanthus bellidiformis* subsp. *bellidiformis*, *Huernia guttata* subsp. *reticulata, Quaqua parviflora* subsp. *dependens*. Graminoid: *Stipa capensis*.

Biogeographically Important Taxon (Knersvlakte endemic) Succulent Herb: *Tromotriche revoluta*.

Endemic Taxa Succulent Shrubs: *Drosanthemum prostratum*, *Lampranthus plenus*. Geophytic Herbs: *Sparaxis roxburghii*, *S. variegata*. Succulent Herb: *Stapelia glanduliflora*.

Conservation Vulnerable, especially due to insular character and surrounding high-intensity agricultural land. The fragmented character and limited extent of this vegetation unit suggest that some localities in the Olifants River valley previously inhabited by this Karoo vegetation have been turned into cultivated land (vineyards, orchards, grain fields). The local-authority Ramskop Nature Reserve (near Clanwilliam) protects some small (albeit already transformed) patches of this vegetation unit. Erosion is very low.

Remark 1 Citrusdal Vygieveld can be seen as the southern continuation of the SKk 5 Vanrhynsdorp Gannabosveld (at least in its northern reaches) due to a number of shared floristic elements and similarities in vegetation structure. While the northern patches of the shale bands support succulent shrublands, increase of renosterveld and Cape thicket elements can be observed along a north-west geographic gradient. The identity of the southernmost patches remains contentious and eventually only more detailed survey research in the area might bring more clarity about the delimitation of the Citrusdal Vygieveld.

Remark 2 A patch of this intravalley Succulent Karoo vegetation was erroneously mapped by Low & Rebelo (1996) as belonging to the Nama-Karoo Biome.

References Milton (1978), Knight et al. (1989), Boucher (1990, 1991, 2003), L. Mucina (unpublished data).

SKk 8 Piketberg Quartz Succulent Shrubland

VT 34 Strandveld of West Coast (100%) (Acocks 1953). LR 62 West Coast Renosterveld (100%) (Low & Rebelo 1996). BHU 31 Swartland Coast Renosterveld (100%) (Cowling & Heijnis 2001).

Distribution Western Cape Province: Piketberg area, larger patch on the Farm Draaihoek between Piketberg and Eendekuil (at eastern foothills of the Piketberg Mountains), in the vicinity of Het Kruis and Redelingshuys (north of Piketberg Mountains) as well as near Sauer at the southwestern foot of the Piketberg Mountains. Altitude 120–160 m.

Vegetation & Landscape Features Low shrubland dominated by sturdy, succulent *Sarcocornia* from the *S. mossiana* complex, and accompanied by leaf-succulent, contracted vygies, especially in shallow trenches and depressions. Elevated sites (hummocks) with deeper soils support dense shrubland.

Geology & Soils This small area is entirely situated on the Porterville Formation (Boland Subgroup) of the Malmesbury Group (Namibian Erathem). Weathering of softer shales left behind hard quartzitic veins which, after disintegration, form an almost continuous quartzite rubble layer. The area is exclusively classified as Db land type.

Climate Low, winter-rainfall precipitation regime (most of the rain falls between May and August, with small peaks in June and August). The area is largely in the local rainshadow of the Piketberg Mountains and located within the already generally dry West Coast region—MAP is only about 270 mm and potential evaporation is very high. The local climate is mild (only 4 frost days per year on average) and MAT (18°C) clearly suggests the classification of the unit as warm-temperate. See also climate diagram for SKk 8 Piketberg Quartz Succulent Shrubland (Figure 5.53).

Important Taxa Succulent Shrubs: *Drosanthemum asperulum* (d), *Galenia sarcophylla* (d), *Sarcocornia* sp. nov. (*Mucina*

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Figure 5.59 SKk 8 Piketberg Quartz Succulent Shrubland: Quartz patch on the Farm Draaihoek near Eendekuil (West Coast lowlands) with an undescribed species of *Sarcocornia* dominant.

200103/8 STEU) (d). Low Shrub: *Athanasia trifurca* (d). Geophytic Herbs: *Albuca longipes*, *Oxalis copiosa*. Succulent Herb: *Psilocaulon parviflorum* (d).

Endemic Taxa Succulent Shrubs: *Drosanthemum zygophylloides* (d), *Diplosoma retroversum*. Herb: *Limonium* sp. nov. (*Mucina 200103/8* STEU) (d). Geophytic Herb: *Drimia barkerae*.

Conservation None of it is conserved in statutory conservation areas, but the major patches of this unit occur on only a few commercial farms, especially on the Farm Draaihoek, where the farm owner (Mr Pierre Rossouw) has so far refrained from utilising the site and effectively pursues its preservation in its original state. Official conservation target 26%. Erosion is low (60%) to very low (40%).

Remark This is an extraordinary vegetation unit physiognomically and ecologically closely linked to Knersvlakte, being effectively separated from Citrusdal Vygieveld only by a ridge of the mountains of the Olifants River a few kilometres broad. There is an interesting evolutionary link between the Knersvlakte Quartz Vygieveld and quartz patches of the Piketberg area in sharing the Knersvlakte endemic genus *Diplosoma* (Aizoaceae), which comprises two species—each endemic to the respective vegetation unit.

References Van Jaarsveld (1998a), Klak (2003), Manning & Goldblatt (2003), L. Mucina (unpublished data).

Trans-Escarpment Succulent Karoo

SKt 1 Western Bushmanland Klipveld

VT 39 False Succulent Karoo (88%) (Acocks 1953). LR 49 Bushmanland Nama Karoo (92%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Northwestern plains of Bushmanland east of Namaqualand Klipkoppe, north and northeast of Kliprand and west of Stofvlei. Altitude 650–1 040 m, with most of the area at 800–1 000 m.

Vegetation & Landscape Features Very sparsely populated plains with a desert appearance (rocky pavements built of rounded, dark-coloured rocks and boulders) supporting succulent dwarf shrubs (*Aridaria, Drosanthemum, Eberlanzia, Phyllobolus, Psilocaulon, Ruschia*), with microphyllous non-succulent shrubs (*Aptosimum, Pentzia*) and drought-tolerant grasses. Occasional mass display of annual spring flora.

Geology & Soils Hutton and Mispah soils over Karoo Sequence sediments (mostly Dwyka diamictite and Ecca shale). The rocky pavements of rounded boulders, which characterise this area, are palaeo-river terraces of the palaeo-Orange River, which is presumed to have flowed south through this area (approximately 22 mya). Fc land type covers the entire region.

Climate Very dry region with MAP only 90 mm (range 70–100 mm), and erratic (almost desert-like) rainfall. Slight peak in precipitation in winter, hardly any in December and January, consistent with the classification of this unit in winter-rainfall Succulent Karoo Biome. Potential evaporation exceeds 2 660 mm. Overall MAT 16–17°C, with clear maxima in December to January. Mean maximum and minimum monthly temperatures in Kliprand are 36°C and –2°C for January and July, respectively. Incidence of frost is relatively high (25 days, range 20–40 days) due to its land-locked position and high altitude generating effect of thermal continentality. See also climate diagram for SKt 1 Western Bushmanland Klipveld (Figure 5.60).

Important Taxa Succulent Shrubs: *Antimima pumila* (d), *Arenifera stylosa* (d), *Augea capensis* (d), *Euphorbia decussata* (d), *Ruschia muricata* (d), *R. robusta* (d), *Salsola glabrescens* (d), *S. tuberculata* (d), *S. zeyheri* (d), *Aridaria noctiflora* subsp. *noctiflora*, *A. noctiflora* subsp. *straminea*, *Galenia sarcophylla*, *Prenia tetragona*, *Sarcocaulon patersonii*, *Tetragonia arbuscula*, *Titanopsis schwantesii*, *Zygophyllum flexuosum*, *Z. lichtensteinianum*. Tall Shrub: *Xerocladia viridiramis*. Low Shrubs: *Eriocephalus spinescens* (d), *Hermannia paucifolia* (d), *Zygophyllum retrofractum* (d), *Aptosimum depressum*, *A. spinescens*, *Asparagus capensis* var. *capensis*, *Eriocephalus ericoides*, *E. microphyllus* var. *pubescens*, *Galenia africana*, *G. fruticosa*, *Lebeckia spinescens*, *Melolobium candicans*, *Oncosiphon piluliferum*, *Osteospermum armatum*, *O. spinescens*, *Pegolettia retrofracta*, *Pentzia spinescens*, *Pteronia glauca*, *P. leucoclada*, *P. mucronata*, *P. sordida*, *Selago albida*, *Solanum capense*, *Tripteris sinuata*, *Zygophyllum microphyllum*. Semiparasitic Shrub: *Thesium lineatum*. Woody Climber: *Asparagus africanus*. Herbs: *Foveolina dichotoma* (d), *Gazania lichtensteinii* (d), *Leysera tenella* (d), *Tribulus terrestris* (d), *Amellus strigosus* subsp. *pseudoscabridus*, *Dicoma capensis*, *Dimorphotheca polyptera*, *Forsskaolea candida*, *Galenia papulosa*, *Helichrysum herniarioides*, *Heliophila variabilis*, *Limeum argute-carinatum* var. *argute-carinatum*, *Osteospermum pinnatum*, *Sesamum capense*. Geophytic Herb: *Drimia intricata*. Succulent Herbs: *Brownanthus vaginatus* (d), *Mesembryanthemum guerichianum*, *M. stenandrum*. Graminoids: *Enneapogon scaber* (d), *Stipagrostis anomala* (d), *S. brevifolia* (d), *S. ciliata* (d), *S. obtusa* (d), *Centropodia glauca*, *Enneapogon desvauxii*, *Schismus barbatus*.

Biogeographically Important Taxon (Western distribution limit) Succulent Shrub: *Euphorbia fusca*.

Endemic Taxa Succulent Shrub: *Salsola henriciae*. Low Shrubs: *Lessertia perennans* var. *polystachya*, *Senecio aquifoliaceus*,

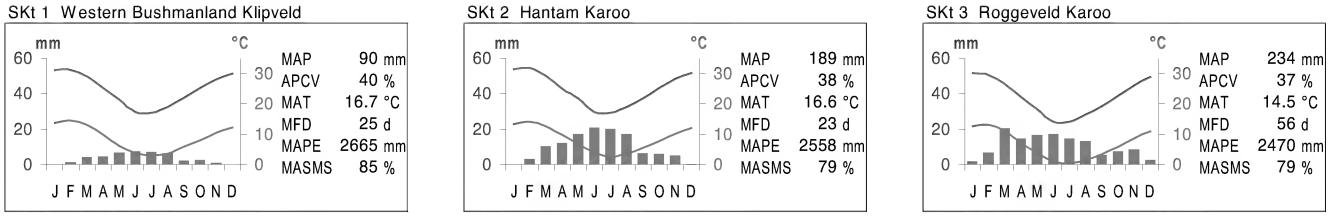

Figure 5.60 Climate diagrams of Trans-Escarpment Succulent Karoo Bioregion units. Blue bars show the median monthly precipitation. The upper and lower red lines show the mean daily maximum and minimum temperature respectively. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days (days when screen temperature was below 0°C); MAPE: Mean Annual Potential Evaporation; MASMS: Mean Annual Soil Moisture Stress (% of days when evaporative demand was more than double the soil moisture supply).

Stachys zeyheri. Herb: *Wahlenbergia albicaulis*. Geophytic Herbs: *Lachenalia glaucophylla*, *Strumaria aestivalis*. Succulent Herb: *Conophytum concordans*.

Conservation Least threatened. Target 18%. None conserved in statutory conservation areas. No signs of serious large-scale transformation or invasion of alien plants. Erosion is high (70%) and moderate (12%).

Remark This unit shows climatic and vegetation characters indicative of a transition between the Succulent and Nama-Karoo Biomes.

References Acocks (1953, 1988), Lloyd (1985, 1989a, b).

SKt 2 Hantam Karoo

VT 28 Western Mountain Karoo (81%) (Acocks 1953). LR 56 Upland Succulent Karoo (88%) (Low & Rebelo 1996).

Distribution Northern (and to a smaller extent also Western) Cape Province: Greater part of the Onder-Bokkeveld and Hantam region between Nieuwoudtville and Calvinia. The unit also encompasses the lower slopes of the Hantamsberg (but not the mountain itself). A small patch of the unit is found north of the Langberg (west of Loeriesfontein)—where, in places, it also moves into the Western Cape Province. Altitude 400 m (in the western part of the unit) to 1 280 m in the east and southeast.

Vegetation & Landscape Features Dwarf Karoo shrubland with nearly equal proportions of succulent elements (*Aloe, Antimima, Euphorbia, Ruschia*) and low microphyllous karroid shrubs, particularly of the family Asteraceae (*Eriocephalus, Pentzia, Pteronia*). Rich displays of spring annuals and geophytes. Vegetation supported by Ag soils shows transitional features towards Nama-Karoo.

Geology & Soils Sediments of the Karoo Sequence (predominantly Ecca Group shales and Dwyka tillites), both significantly intruded by dykes and sills of the Jurassic Karoo Dolerite Suite. About half of the region is classified as Fc land type, followed by Fb, Ag and Da.

Climate Arid area (MAP around 190 mm and MAPE more than 2 550 mm), with clear peak in June to July and hardly any notable precipitation in December and January—characters typical of winter-rainfall regime. MAT 16–17°C and incidence of frost high (for the same reasons as with SKt 1 Western Bushmanland Klipveld). See also climate diagram for SKt 2 Hantam Karoo (Figure 5.60).

Important Taxa Succulent Shrubs: *Antimima hallii*, *A. hantamensis*, *Aridaria noctiflora* subsp. *straminea*, *Drosanthemum framesii, Lampranthus watermeyeri*, *Lycium cinereum*, *Manochlamys albicans*, *Pelargonium crithmifolium*, *Ruschia fugitans*, *Salsola aphylla*, *S. namibica*, *Stomatium mustellinum*, *Tetragonia robusta* var. *psiloptera*, *Tylecodon wallichii* subsp. *wallichii*, *Zygophyllum flexuosum*. Low Shrubs: *Eriocephalus*

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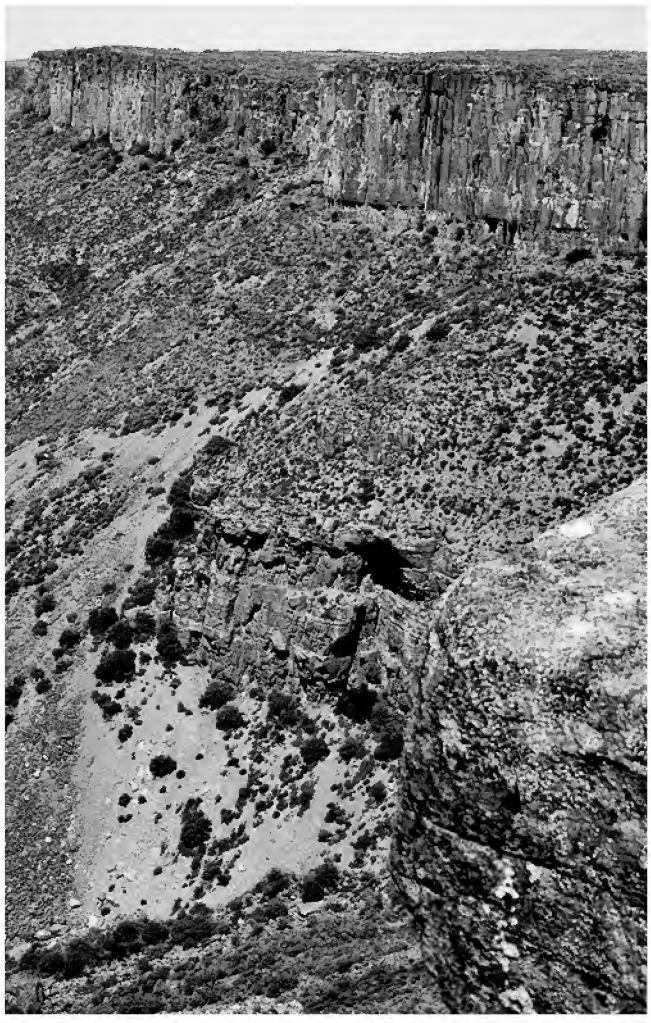
Figure 5.61 SKt 2 Hantam Karoo: Endemic *Dorotheanthus maughanii* in succulent karoo shrubland near Calvinia (Northern Cape) in spring.



L.W. Powrie

Figure 5.62 SKt 2 Hantam Karoo: Top of Akkerendam Nature Reserve near Calvinia as viewed from the top of the Hantamsberg.

purpureus (d), *Hermannia cuneifolia* (d), *Hirpicium alienatum* (d), *Pentzia incana* (d), *Pteronia incana* (d), *Asparagus capensis* var. *capensis*, *Chrysocoma ciliata*, *Eriocephalus ericoides*, *E. pauperrimus*, *E. spinescens*, *Galenia africana*, *G. fruticosa*, *Hermannia multiflora*, *Pteronia erythrochaeta*, *P. glauca*, *P. glomerata*, *P. intermedia*, *P. oblanceolata*, *Tripteris sinuata*, *Zygophyllum microphyllum*. Semiparasitic Shrub: *Thesium lineatum*. Woody Climbers: *Asparagus fasciculatus*, *A. multituberosus*, *Microloma sagittatum*. Herbs: *Amellus tridactylus*, *Cotula microglossa*, *Dimorphotheca tragus*, *Gazania rigida*, *Leysera tenella*, *Pelargonium minimum*, *P. nervifolium*, *Plantago cafra*, *Ursinia nana*. Geophytic Herbs: *Drimia intricata*, *Gethyllis linearis*, *Moraea ciliata*, *Oxalis pes-caprae*, *Wurmbea variabilis*. Succulent Herbs: *Aloe variegata*, *Brownanthus vaginatus*, *Conophytum roodiae* subsp. *roodiae*, *Crassula muscosa*, *Duvalia caespitosa* subsp. *caespitosa*, *Hoodia flava, Mesembryanthemum guerichianum*, *Notechidnopsis tessellata, Orbea ciliata, Piaranthus geminatus* subsp. *decorus, P. punctatus, Psilocaulon junceum*, *Quaqua acutiloba, Q. arida, Q. incarnata* subsp. *tentaculata*, *Q. multiflora, Stapeliopsis exasperata, S. saxatilis, Tetragonia microptera, Tromotriche pedunculata* subsp. *pedunculata*. Graminoids: *Dregeochloa calviniensis*, *Ehrharta calycina*, *Karroochloa tenella*.

Biogeographically Important Taxa ([RH]Roggeveld-Hantam endemic, [N]Northern distribution limit, [W]Western distribution limit, [E]Eastern distribution limit) Succulent Shrubs: *Antimima androsacea*[RH], *A. prolongata*[RH], *Euphorbia aequoris*[W], *E. cylindrica*[W], *E. pillansii*[W], *Hertia ciliata*[W]. Low Shrubs: *Felicia whitehillensis*[N], *Hermannia grandiflora*[W], *H. johanssenii*[RH], *Pteronia adenocarpa*[W], *Rosenia glandulosa*[W], *Stachys aurea*[RH]. Herbs: *Alyssum minutum*[RH], *Cromidon austerum*[RH], *C. plantaginis*[RH], *C. varicalyx*[RH], *Diascia cardiosepala*[RH], *D. macrophylla*[RH], *Galeomma oculus-cati*[RH], *Hemimeris centrodes*[RH], *Hermannia erodioides*[W], *Jamesbrittenia thunbergii*[RH], *Lotononis lenticula*[W], *Nemesia leipoldtii*[RH], *Zaluzianskya cohabitans*[RH], *Z. inflata*[RH], *Z. minima*[RH], *Z. violacea*[RH]. Geophytic Herbs: *Androcymbium hantamense*[RH], *Babiana spathacea*[RH], *Bulbinella elegans*[RH], *Geissorhiza corrugata*[RH], *Haemanthus barkerae*[RH], *Ixia curvata*[RH], *Moraea bifida*[RH], *M. marlothii*[RH], *M. pritzeliana*[RH], *Pelargonium articulatum*[RH], *Romulea atrandra*[N], *Strumaria truncata*[E]. Succulent Herbs: *Quaqua aurea*[RH], *Pectinaria articulata* subsp. *articulata*[RH], *P. longipes* subsp. *longipes*[RH], *Stapelia resurrecta*[RH]. *Tromotriche thudichumii*[RH].

Endemic Taxa Succulent Shrubs: *Aloinopsis malherbei*, *Antimima distans*, *A. gracillima*, *A. stayneri*, *Cephalophyllum hallii*, *Drosanthemum glabrescens*, *Ruschia punctulata*. Geophytic Herbs: *Androcymbium crispum*, *Lachenalia dasybotrya*, *Moraea hesperantha*, *M. pseudospicata*, *Ornithogalum rotatum*, *Oxalis pulvinata*, *Polyxena maughanii*. Succulent Herbs: *Dorotheanthus maughanii* (d), *Pectinaria longipes* subsp. *villetii, P. maughanii, Quaqua parviflora* subsp. *swanepoelii, Stapelia villetiae*.

Conservation Least threatened. Target 18%. Only a small patch is statutorily conserved in Akkerendam Nature Reserve near Calvinia. Transformation rate is low and invasions of alien plants have not been identified as a problem yet. Erosion is moderate (73%) and high (18%).

Remark 1 Hantam Karoo (including this unit as well as FRd 1 Nieuwoudtville-Roggeveld Dolerite Renosterveld and FRd 2 Hantam Plateau Dolerite Renosterveld), the neighbouring Roggeveld (see Van Wyk & Smith 2001), to which we would also add the marginal regions surrounding the Tanqua Basin from the west, and possibly also the SKv 6 Koedoesberge-Moordenaars Karoo, forms an important centre of endemism. Remarkable is the concentration of endemic Scrophulariaceae (many of them short-lived), including *Alonsoa*, *Cromidon, Diascia, Hemimeris, Zaluzianskya* as well as bulbous and cormous geophytes of the Hyacinthaceae, Iridaceae and Amaryllidaceae.

Remark 2 This vegetation unit borders on Tanqua Karoo in the south and differs from it by a higher vegetation cover of microphyllous shrubs and a greater diversity of species, especially geophytes. The spring displays of annual Asteraceae and Scrophulariaceae are striking in years of good rainfall.

References Snijman & Perry (1987), Manning & Goldblatt (1997), Van Wyk & Smith (2001), L. Mucina (unpublished data).

SKt 3 Roggeveld Karoo

VT 28 Western Mountain Karoo (69%) (Acocks 1953). LR 56 Upland Succulent Karoo (69%) (Low & Rebelo 1996).

Distribution Northern (and to a very small extent also Western) Cape Province: Keiskiesberg and Kapgat se Berge southeast of Calvinia, surrounds of Sutherland and Hondefontein as far west as Teekloof Pass in the Nuweveld Mountains southeast of Fraserburg: the area constitutes a gradually sloping plateau situated inland of the Roggeveld Escarpment towards the Bushmanland Basin. Only negligible patches of this vegetation type move into Western Cape Province in the Besemgoedberge area (Nuweveld Mountains region). Altitude 1 040–1 680 m.

Vegetation & Landscape Features Diverse landscape including vast stretches of slightly undulating hills, steeper mountain slopes as well as extensive slightly sloping plateaus. The dominant image of the vegetation is sparse dwarf shrubland with high proportions of both succulent and nonsucculent (low microphyllous shrubs). The dominant shrubby genera include *Antimima, Eriocephalus, Pentzia, Pteronia* and *Salsola*. The occurrence and structural appearance of grasses (*Aristida, Stipagrostis*, but also *Ehrharta*) is notable and probably one of the most striking features within Succulent Karoo units—all these characters indicate the transitional position of Roggeveld Karoo between the Succulent Karoo and Nama-Karoo Biomes.

Geology & Soils The area is dominated by Adelaide Subgroup mudrock and subordinate sandstone (Beaufort Group, Karoo Sequence), with Ecca Group shale and sandstone found in the northeast (Waterford and Volksrust Formations). Karoo dolerites are found throughout the area. Fc land type dominates the region, while Da land type is also present.

Climate Roggeveld is climatically one of the most peculiar regions of southern Africa due to the unusual combination of high altitude, a land-locked continental position and a transitional position between two major climatic systems responsible for winter- and summer-rainfall regimes. It is a semidesert region under slight influence of a rainshadow (the area slopes landwards, away from the elevated Escarpment), with MAP reaching around 230 mm. Pronounced precipitation peaks are in March and June, and the overall precipitation in December to January is markedly lower than during the rest of the year. MAT 14–15°C, but the high frequency of low temperatures in autumn and winter resulting in an average of 56 frost days per year, has won the region (the town of Sutherland in particular) the reputation as the coldest place in South Africa. Clear skies (low cloudiness due to overall dry climate and high altitude as well as remoteness from major settlements and especially sources of air pollution) put Sutherland on the world map of astronomy through its famous telescope centre built near the town. See also climate diagram for SKt 3 Roggeveld Karoo (Figure 5.60).

Important Taxa Succulent Shrubs: *Lycium cinereum* (d), *Antimima pumila*, *A. subtruncata*, *Aridaria noctiflora* subsp. *straminea*, *Euphorbia stolonifera*, *Exomis microphylla* var. *axyrioides*, *Galenia sarcophylla*, *Salsola glabrescens*, *S. tuberculata*, *Tetragonia arbuscula*, *Zygophyllum flexuosum*. Low Shrubs: *Chrysocoma ciliata* (d), *Eriocephalus ericoides* (d), *E. spinescens* (d), *Felicia muricata* (d), *Helichrysum lucilioides* (d), *Pentzia spinescens* (d), *Pteronia glauca* (d), *P. glomerata* (d), *Amphiglossa triflora*, *Aptosimum elongatum*, *Asparagus capensis* var. *capensis*, *Chrysocoma coma-aurea*, *Eriocephalus decussatus*, *E. pauperrimus*, *Euryops imbricatus*, *E. lateriflorus*, *E. multifidus*, *Felicia macrorrhiza*, *F. ovata*, *Galenia africana*, *Hermannia multiflora*, *Limeum aethiopicum*, *Melolobium candicans*, *Osteospermum leptolobum*, *O. spinescens*, *Pentzia globosa*, *Plinthus karooicus*, *Pteronia adenocarpa*, *P. oblanceolata*, *P. tricephala*, *Rosenia glandulosa*, *R. humilis*, *R. oppositifolia*, *Senecio angustifolius*, *Stachys cuneata*, *Zygophyllum microphyllum*. Semiparasitic Shrub: *Thesium lineatum*. Woody Climber: *Asparagus multituberosus*. Herbs: *Leysera tenella* (d), *Alonsoa unilabiata*, *Amellus strigosus* subsp. *pseudoscabridus*, *Arctotheca calendula*, *Gazania jurineifolia* subsp. *scabra*, *Lepidium desertorum*, *Osteospermum acanthospermum*, *Pelargonium minimum*, *Ursinia nana*. Geophytic Herbs: *Drimia intricata* (d), *Androcymbium ciliolatum*, *Bulbine asphodeloides*, *Drimia physodes*, *Empodium plicatum*, *Geissorhiza spiralis*, *Ixia marginifolia*, *Moraea pallida*, *Oxalis densa*, *O. obtusa*, *Strumaria karooica*. Succulent Herbs: *Deilanthe thudichumii*, *Mesembryanthemum guerichianum*, *M. stenandrum*, *Othonna auriculifolia*, *O. rechingeri*, *Tripteris aghillana* var. *integrifolia*. Graminoids: *Aristida diffusa* (d), *Ehrharta calycina* (d), *Stipagrostis ciliata* (d), *S. obtusa* (d), *Chaetobromus involucratus* subsp. *dregeanus*, *Ehrharta capensis*, *E. pusilla*, *Karroochloa tenella*.

Biogeographically Important Taxa ([RH]Roggeveld-Hantam endemic, [W]Western distribution limit) Succulent Shrubs: *Antimima androsacea*[RH], *A. prolongata*[RH]. Low Shrubs: *Pentzia punctata*[W], *Pteronia aspalatha*[RH], *Selago articulata*[RH]. Herbs: *Alyssum minutum*[RH], *Corycium deflexum*[RH], *Cromidon austerum*[RH], *C. decumbens*[RH], *C. hamulosum*[RH], *C. plantaginis*[RH], *Diascia macrophylla*[RH], *Galeomma oculus-cati*[RH], *Gazania othonnites*[RH], *Heliophila pubescens*[RH], *Hemimeris centrodes*[RH], *Lotononis maximiliani*[RH], *Polycarena aurea*[RH], *Zaluzianskya cohabitans*[RH], *Z. minima*[RH], *Z. violacea*[RH]. Geophytic Herbs: *Androcymbium hantamense*[RH], *Bulbinella elegans*[RH], *Eriospermum marginatum*[RH], *Gladiolus pritzelii*[RH], *G. uysiae*[RH], *Hesperantha ciliolata*[RH], *H. cucullata*[RH], *H. luticola*[RH], *H. marlothii*[RH], *H. pseudopilosa*[RH], *H. teretifolia*[RH], *Ixia curvata*[RH], *Lapeirousia montana*[RH], *Moraea bifida*[RH], *M. marlothii*[RH], *M. pritzeliana*[RH], *R. membranacea*[RH], *R. monadelpha*[RH], *R. syringodeoflora*[RH], *R. tetragona* var. *tetragona*[RH], *R. unifolia*[RH], *Syringodea unifolia*[RH]. Succulent Herb: *Pectinaria articulata* subsp. *articulata*[RH]. Graminoids: *Helictotrichon namaquense*[RH], *Pentaschistis aristifolia*[RH], *Secale strictum* subsp. *africanum*[RH].

Endemic Taxa Succulent Shrubs: *Drosanthemum eburneum* (d), *Aloinopsis spathulata*, *Antimima emarcescens*, *Hammeria gracilis*. Low Shrub: *Polhillia involucrata*. Herb: *Reyemia nemesioides*. Geophytic Herbs: *Babiana virginea*, *Moraea contorta*, *M. fistulosa*, *Romulea albiflora*. Succulent Herbs: *Dorotheanthus booysenii*, *Phyllobolus amabilis*.

Conservation Least threatened and none of the area is conserved in statutory conservation areas. Target 18%. Transformed only to a very small extent (about 2%) and hardly suffering invasions of alien plants. Erosion is moderate (71%) and low (29%).

Remarks Roggeveld Karoo is a botanically poorly researched vegetation type and this despite its intriguing transitional position between three major biomes (Fynbos, Succulent Karoo and Nama-Karoo) and high level of local endemism (see SKt 2 Hantam Karoo for more details). The classification of the unit itself into a biome still remains a contentious issue demanding research into vegetation and phytogeography patterns (and history) of the SKt 3 Roggeveld Karoo as well as the spatially and floristically associated units such as FRd 1 Nieuwoudtville-Roggeveld Dolerite Renosterveld, FRs 3 Roggeveld Shale Renosterveld and SKv 4 Tanqua Escarpment Shrubland.

Reference Van Wyk & Smith (2001).

Rainshadow Valley Karoo

SKv 1 Doringrivier Quartzite Karoo

VT 31 Succulent Karoo (68%) (Acocks 1953). Dry Mountain Fynbos (77%) (Moll & Bossi 1984). LR 64 Mountain Fynbos (78%) (Low & Rebelo 1996). BHU 46 Gifberg Mountain Fynbos Complex (77%) (Cowling & Heijnis 2001).

Distribution Western Cape Province: Valley of the Doring River (from Doringbos and the bottom of the Botterkloof) to the confluence of the Doring and Olifants Rivers. It also includes the broader surrounds of Knolvlei (north of Pakhuis Pass, north of Clanwilliam) and a small patch of the Karoo east of Trawal and southwest of Klawer. Altitude 60–500 m.

Vegetation & Landscape Features Slopes of low mountains and of deep river canyons as well as table lands supporting shrublands housing a mixture of growth forms including tall

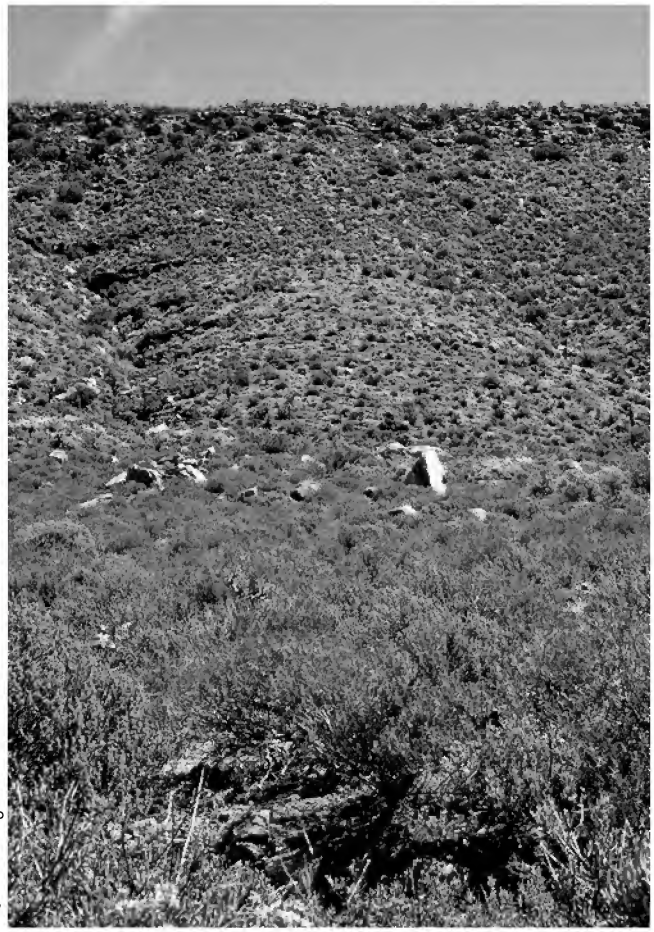


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Figure 5.63 SKv 1 Doringrivier Quartzite Karoo: Succulent shrublands in the Botterkloof in the Doring River Valley (Western Cape).

shrubs (*Diospyros ramulosa, Montinia caryophyllacea, Berkheya fruticosa*) and low succulent shrubs, for example *Ruschia, Tylecodon, Euphorbia* and *Zygophyllum*.

Geology & Soils Here the Doring River cuts mostly through Table Mountain Group quartzites as well as some Bokkeveld Group (Nardouw Subgroup) sandstone and shale (both of Cape Supergroup). Ia , Ic and Ah land types are equally important.

Climate Semidesert region (obviously accentuated by the rain-shadow of deeply incised valleys) with MAP reaching almost 200 mm and MAPE exceeding 2 500 mm. Pronounced concentration of precipitation in winter (June, July, August). December to February have very low (and erratic) rainfall. Incidence of frost is very low. See also climate diagram for SKv 1 Doringrivier Quartzite Karoo (Figure 5.65).

Important Taxa Succulent Shrubs: *Euphorbia mauritanica* (d), *Ruschia brevibracteata* (d), *Didelta spinosa*, *Euphorbia burmannii*, *Tetragonia arbuscula*, *T. fruticosa*, *T. spicata*, *Tylecodon paniculatus*, *T. wallichii* subsp. *wallichii*. Tall Shrubs: *Diospyros ramulosa* (d), *Montinia caryophyllacea* (d), *Rhus undulata*, *Wiborgia obcordata*. Low Shrubs: *Berkheya fruticosa* (d), *Galenia africana* (d), *Eriocephalus africanus*, *Galenia fruticosa*, *Helichrysum hebelepis*, *Hermannia trifurca*, *Pteronia ovalifolia*, *Tripteris sinuata*. Woody Climber: *Cissampelos capensis*. Herb: *Lessertia pauciflora*. Geophytic Herb: *Chlorophytum lewisiae*. Graminoids: *Ehrharta villosa* var. *villosa* (d), *E. calycina*, *E. thunbergii*, *Pentaschistis airoides*.

Conservation Ranked as least threatened, but some important stretches might be destroyed by plans to build dams in certain rivers. Target 19%. None conserved in statutory conservation areas. About 15% has been transformed for cultivation. Aliens do not play a major role. Erosion is low (52%) especially due to low erodibility of hard sandstone rocks, moderate (25%) and very low (23%).

Remark Intrusion of the Succulent Karoo vegetation onto hard quartzitic sandstones is a relatively rare phenomenon occurring only in climatically marginal (dry) regions such as edges of the Tanqua Basin (SKv 2 Swartruggens Quartzite Karoo) and the adjacent Doring River Valley with the SKv 1 Doringrivier Quartzite Karoo.

Reference Boucher (2003).

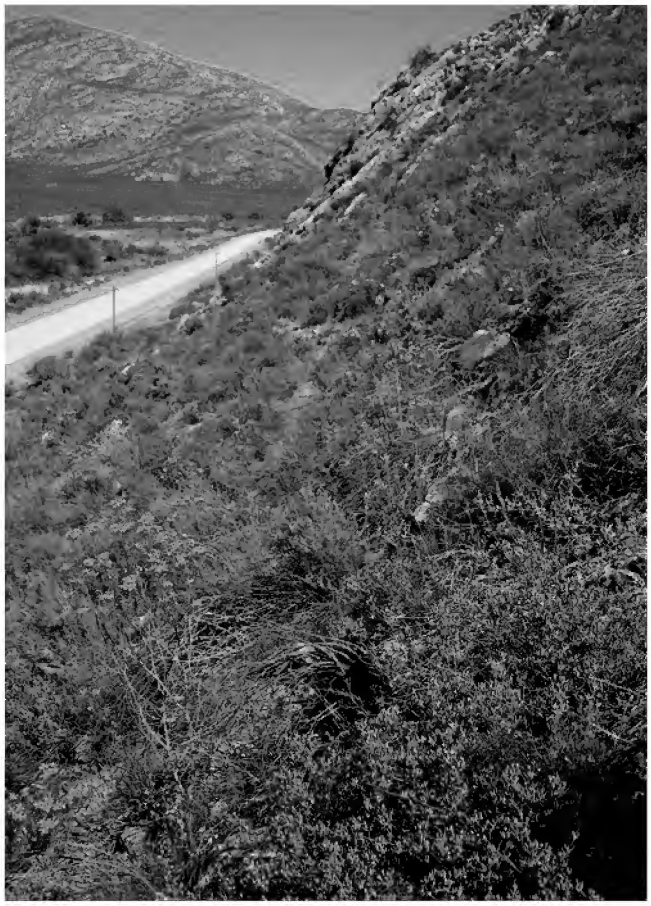
SKv 2 Swartruggens Quartzite Karoo

VT 31 Succulent Karoo (91%) (Acocks 1953). LR 57 Lowland Succulent Karoo (96%) (Low & Rebelo 1996). BHU 78 Tanqua Vygieveld (94%) (Cowling & Heijnis 2001).

Distribution Western and Northern Cape Provinces: Hottentotsberge and eastern portions of the Swartruggens bordering on the Tanqua Basin—from the canyon of the Doring River (leaving the Tanqua Karoo Basin at Elandsvlei) in the north to the Karoopoort (east of Ceres) in the south. Altitude 300–1 180 m.

Vegetation & Landscape Features Hilly landscape dissected by valleys with steep rocky slopes housing succulent shrublands with *Euphorbia, Tylecodon, Phiambolia*. Fynbos and renosterveld elements, shared with the neighbouring dry sandstone fynbos units, such as *Willdenowia, Dodonaea* and *Elytropappus*, are also important.

Geology & Soils Quartzitic sandstones of the Witteberg Group (Cape Supergroup) supporting shallow, skeletal soils (mainly Mispah soil form). Ib land type is dominant.



L. Mucina

Figure 5.64 SKv 2 Swartruggens Quartzite Karoo: Steep quartzite slopes of Karoopoort (northeast of Ceres) supporting succulent karoo shrubland with *Euphorbia mauritanica* (Euphorbiaceae) and *Euryops tenuissimus* (Asteraceae).

Climate Winter-rainfall regime with clear precipitation optimum from June to August. MAP is around 200 mm (semidesert). MAT 15–16°C. Incidence of frost in midrange in comparison with other units of the Rainshadow Valley category (SKv). See also climate diagram for SKv 2 Swartruggens Quartzite Karoo (Figure 5.65).

Important Taxa ([S]Deep sandy soils) Succulent Shrubs: *Euphorbia decussata*[S] (d), *E. mauritanica* (d), *Tylecodon wallichii* subsp. *wallichii* (d), *Aloe comosa*, *Euphorbia hamata*, *Tylecodon paniculatus*. Tall Shrubs: *Dodonaea viscosa* var. *angustifolia*, *Rhus undulata*. Low Shrubs: *Euryops tenuissimus* (d), *Gnidia deserticola* (d), *Elytropappus rhinocerotis*, *Eriocephalus africanus*, *Hoplophyllum spinosum, Pelargonium magenteum*. Herb: *Gazania lichtensteinii* (d), *Ursinia anthemoides* subsp. *versicolor* (d), *Rhynchopsidium pumilum, Ursinia nana*. Geophytic Herb: *Xenoscapa fistulosa*. Graminoid: *Willdenowia incurvata*[S].

Endemic Taxa Succulent Shrubs: *Cephalophyllum alstonii*, *Phiambolia franciscii*, *P. hallii*, *Tylecodon stenocaulis*.

Conservation Least threatened. Target 19%. About 5% statutorily conserved in Matjiesrivier Nature Reserve. Only a very small portion transformed for cultivation. No signs of serious alien plant infestations. Erosion is very low (55%) and low (43%).

Remark This vegetation type is the developmental centre of the recently recognised (Klak 2003) endemic succulent genus *Phiambolia* (Aizoaceae).

References Lechmere-Oertel (1998), Lechmere-Oertel & Cowling (1999, 2001), Klak (2003).

SKv 3 Agter-Sederberg Shrubland

VT 31 Succulent Karoo (37%), VT 69 Macchia (Fynbos) (33%) (Acocks 1953). LR 57 Lowland Succulent Karoo (41%), LR 56 Upland Succulent Karoo (33%) (Low & Rebelo 1996). BHU 78 Tanqua Vygieveld (41%), BHU 75 Western Mountain Vygieveld (33%) (Cowling & Heijnis 2001).

Distribution Western (and to a lesser extent also Northern) Cape Province: Includes Stinkfonteinberge and Boegoeberge (with the botanically famous Botterkloof), Biedouberge and Tra-Traberge near Wuppertal as well as a very narrow (shale) belt extending south of Wuppertal and squeezed between the Skurweberg in the west and Swartruggens in the east. Altitude 220–1 320 m (most of the area at 340–780 m).

Vegetation & Landscape Features Slopes of low mountains and deeply incised valleys supporting tall shrublands composed of mixture of nonsucculent (*Berkheya, Felicia, Pteronia*) and succulent (*Crassula, Euphorbia, Ruschia, Tylecodon*) shrubs.

Geology & Soils Dark grey siltstones and shales with intercalated mudstones and sandstones of the Devonian Ceres and Bidouw Subgroups (Bokkeveld Group) and quartzitic sandstones of the Witteberg Group and Nardouw Subgroup (Table Mountain Group). Supporting deep soils over shales and shallow soils over quartzitic sandstone. Most of the area is classified as Fb land type. Fa and Fc land types are of lesser importance.

Climate Typical winter-rainfall regime with most of the rain falling between June and August. MAP is about 250 mm, which is higher than the nearby quartzite Karoo units and especially the neighbouring Tanqua Karoo. MAT reaches almost 17°C and incidence of frost is relatively low. See also climate diagram for SKv 3 Agter-Sederberg Shrubland (Figure 5.65).

Important Taxa Succulent Shrubs: *Aridaria noctiflora* subsp. *noctiflora* (d), *Euphorbia burmannii* (d), *E. mauritanica* (d), *Leipoldtia schultzei* (d), *Tetragonia fruticosa* (d), *Tylecodon wallichii* subsp. *wallichii* (d), *Adromischus mammillaris*, *Cotyledon orbiculata* var. *orbiculata*, *Crassula subaphylla*, *Didelta spinosa*, *Euphorbia caterviflora*, *Exomis microphylla* var. *axyrioides*, *Tetragonia robusta* var. *psiloptera*, *T. verrucosa*, *Tylecodon paniculatus*. Tall Shrubs: *Wiborgia obcordata* (d), *Euclea tomentosa*, *Montinia caryophyllacea*, *Nylandtia spinosa*, *Rhus incisa*, *R. pallens*. Low Shrubs: *Asparagus stipulaceus* (d), *Berkheya fruticosa* (d), *Galenia africana* (d), *Helichrysum cylindriflorum* (d), *Struthiola leptantha* (d), *Asparagus capensis* var. *capensis*, *Elytropappus rhinocerotis*, *Eriocephalus africanus*, *Euryops tenuissimus*, *Galenia fruticosa*, *Helichrysum hebelepis*, *Indigofera heterophylla*, *Prenia pal-*

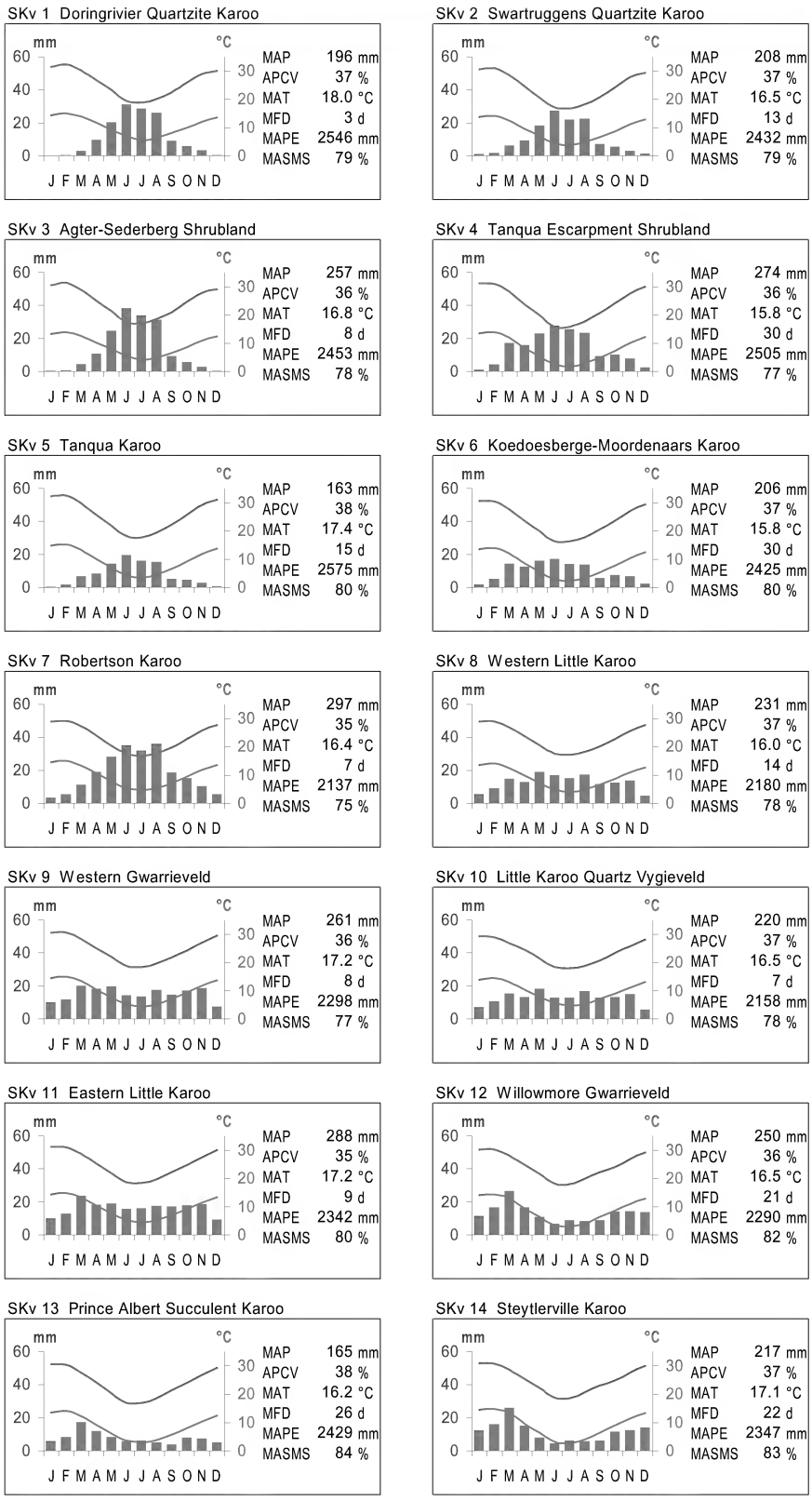


Figure 5.65 Climate diagrams of Rainshadow Valley Karoo Bioregion units. Blue bars show the median monthly precipitation. The upper and lower red lines show the mean daily maximum and minimum temperature respectively. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days (days when screen temperature was below 0°C); MAPE: Mean Annual Potential Evaporation; MASMS: Mean Annual Soil Moisture Stress (% of days when evaporative demand was more than double the soil moisture supply).

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Figure 5.66 SKv 3 Agter-Sederberg Shrubland: Shrubland at lower western foothills of Blinkberg near Op-die-Berg in the Koue Bokkeveld.

lens subsp. *lancea*, *Pteronia divaricata*, *P. incana*, *P. paniculata*, *Tripteris sinuata*, *Wiborgia sericea*. Semiparasitic Shrub: *Thesium lineatum*. Woody Climber: *Microloma sagittatum*. Herbs: *Felicia bergeriana* (d), *Oncosiphon suffruticosum* (d), *Plantago cafra* (d), *Rhynchopsidium pumilum* (d), *Osteospermum pinnatum*, *Sutera caerulea*, *Tripteris breviradiata*. Succulent Herbs: *Psilocaulon junceum* (d), *Crassula alpestris* subsp. *alpestris*, *C. muscosa*, *C. tomentosa*, *Quaqua mammillaris*. Graminoids: *Tribolium pusillum* (d), *Ehrharta calycina*, *E. longiflora*, *Pentaschistis patula*, *Tribolium echinatum*.

Biogeographically Important Taxon (Southern distribution limit) Succulent Shrub: *Lampranthus watermeyeri*.

Endemic Taxa Low Shrub: *Aspalathus bidouwensis*. Succulent Shrub: *Euphorbia hallii*. Geophytic Herbs: *Pelargonium punctatum*, *Strumaria watermeyeri* subsp. *botterkloofensis*.

Conservation Least threatened. Target 19%. Only a small patch statutorily conserved in Matjiesrivier Nature Reserve and only about 2–3% transformed for cultivation. No serious alien infestation. Erosion covers all possible categories, from very low (17%), low (11%) and high (10%).

Remark Agter-Sederberg Shrubland is a very poorly studied vegetation type promising new taxonomic surprises.

Reference Klak (2003).

SKv 4 Tanqua Escarpment Shrubland

VT 28 Western Mountain Karoo (68%) (Acocks 1953). LR 56 Upland Succulent Karoo (51%) (Low & Rebelo 1996).

Distribution Western Cape Province: Narrow belt on northwest-facing slopes of the Klein-Roggeveldberge and on southwest-facing and west-facing slopes of the Roggeveld Escarpment as far north as (and west of) Bloukrans Pass (south of Calvinia). Altitude 620–1 600 m (most of the area between 720–1 220 m).

Vegetation & Landscape Features Steep flanks below an escarpment overlooking a basin, generally facing southwest supporting succulent shrubland of medium height with *Tylecodon* (botterboom) and *Euphorbia mauritanica* (melkboom) prominent and with undergrowth of both succulent (*Aridaria*, *Crassula*) and nonsucculent (*Asparagus, Pteronia*) shrubs.

Geology & Soils Mudrocks of the Adelaide Subgroup (Beaufort Group) and Permian Volksrust Formation (Ecca Group) as well as brown to grey shale, siltstone and sandstone of the Permian Waterford Formation (also Ecca Group), broken by network of intrusive Jurassic Karoo dolerites. The shallow soils form the basis for the classification of most of the area into Ib land type (with Dc land type being of lesser importance).

Climate Less pronounced winter-rainfall regime with most of the rainfall spread between March and August (peaking from June to August). MAT is almost 16°C and the incidence of frost is relatively high (30 days). See also climate diagram for SKv 4 Tanqua Escarpment Shrubland (Figure 5.65).

Important Taxa Succulent Shrubs: *Tylecodon paniculatus* (d), *T. wallichii* subsp. *wallichii* (d), *Aridaria noctiflora* subsp. *straminea*, *Crassula tetragona* subsp. *connivens*, *Drosanthemum lique*, *Euphorbia caterviflora*, *E. mauritanica*, *Lycium cinereum*, *Manochlamys albicans*, *Tetragonia robusta* var. *psiloptera*, *Tylecodon ventricosus*. Tall Shrubs: *Diospyros austro-africana*, *Gomphocarpus fruticosus*, *Montinia caryophyllacea*, *Rhus burchellii*, *R. undulata*. Low Shrubs: *Pteronia incana* (d), *Asparagus capensis* var. *capensis*, *A. striatus*, *Berkheya*

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Figure 5.67 SKv 4 Tanqua Escarpment Shrubland: Succulent shrubland with *Tylecodon paniculatus* (Crassulaceae) and *Salvia disermas* (Lamiaceae) on slopes of the Bloukrans Pass linking the Tanqua Karoo with the Hantam Plateau.

cardopatifolia, *Chrysocoma ciliata*, *Eriocephalus africanus*, *E. ericoides*, *E. spinescens*, *Felicia filifolia*, *F. macrorrhiza*, *F. scabrida*, *Galenia africana*, *G. fruticosa*, *Heliophila cornuta* var. *squamata*, *Hermannia multiflora*, *Lessertia fruticosa*, *Limeum aethiopicum*, *Pelargonium grandicalcaratum*, *Pteronia oblanceolata*, *P. sordida*, *Salvia disermas*, *Selago albida*, *S. polycephala*, *Tripteris sinuata*, *Ursinia pilifera*. Semiparasitic Shrub: *Thesium lineatum*. Woody Climbers: *Asparagus fasciculatus*, *A. multituberosus*, *Microloma sagittatum*. Herbaceous Climber: *Fockea sinuata*. Herbs: *Galium capense* subsp. *garipense*, *Lasiospermum brachyglossum*, *Leysera tenella*, *Pelargonium moniliforme*, *Tripteris microcarpa*. Geophytic Herbs: *Androcymbium volutare*, *Asplenium cordatum*, *Boophone disticha*, *Cyanella hyacinthoides*, *Empodium plicatum*, *Oxalis obtusa*. Succulent Herbs: *Crassula tomentosa*, *C. umbella*, *Tetragonia microptera*. Graminoids: *Ehrharta calycina*, *Fingerhuthia africana*, *Merxmuellera dura*.

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Figure 5.68 SKv 5 Tanqua Karoo: Extremely thin vegetation cover of the central Tanqua Karoo (near Jakkalsfontein), some years receiving as little as 40 mm of rainfall.

Biogeographically Important Taxa ([RH]Roggeveld-Hantam endemic, [S]Southern distribution limit, [W]Western distribution limit) Low Shrubs: *Felicia burkei*[S], *Nenax cinerea*[RH], *Pelargonium magenteum*[RH], *Pteronia aspalatha*[RH], *Selago polygala*[RH], *Stachys aurea*[RH]. Herbs: *Cromidon hamulosum*[RH], *Diascia macrophylla*[RH], *Jamesbrittenia thunbergii*[RH], *Lotononis maximiliani*[RH], *Nemesia anisocarpa*[S], *Polycarena aurea*[RH], *Trigonocapnos lichtensteinii*[RH]. Succulent Herb: *Crassula dodii*[RH]. Graminoids: *Ehrharta melicoides*[W], *Secale strictum* subsp. *africanum*[RH].

Endemic Taxon Low Shrub: *Indigofera hantamensis*.

Conservation Least threatened. Target 19%. Only a very small portion statutorily conserved in Tankwa Karoo National Park. No visible signs of transformation or invasion of alien plants. Erosion is moderate (59%) and low (41%).

Remark Tanqua Escarpment Shrubland is part of the Hantam-Roggeveld Centre of Endemism (Van Wyk & Smith 2001) and remains one of the least studied vegetation types of the country.

Reference Van Wyk & Smith (2001).

SKv 5 Tanqua Karoo

VT 31 Succulent Karoo (84%) (Acocks 1953). LR 57 Lowland Succulent Karoo (80%) (Low & Rebelo 1996). BHU 78 Tanqua Vygieveld (50%) (Cowling & Heijnis 2001).

Distribution Western and Northern Cape Provinces: Basin encompassing valleys of Tanqua and Doring Rivers located between Cederberg (Swartruggens) in the west, the Roggeveld Escarpment in the east and Klein Roggeveld Mountains in the southeast; towards the north this unit borders on higher elevated plains of the Hantam Karoo. Altitude 240–960 m (most of the area at 300–450 m).

Vegetation & Landscape Features Slightly undulating intramountain basin sheltered by steep slopes of mountain ranges. The plain is interrupted by a series of solitary dolerite butts and elevated ridges, extensive, flat sheet-washes and deeper incised channels of intermittent rivers (these habitats support vegetation of the AZi 7 Tanqua Wash Riviere). The plains are very sparsely vegetated (low succulent shrubland with *Ruschia, Drosanthemum, Aridaria, Augea, Zygophyllum*), in extreme precipitation-poor years appearing barren, while the slopes of the koppies and adjacent mountain piedmonts support well-developed medium-tall succulent *Euphorbia hamata–Pteronia incana* shrubland (Rubin 1998). Small quartz patches occur in the southern Tanqua Basin. Annual flora (*Gazania lichtensteinii, Euryops annuus, Ursinia nana*) becomes conspicuous with sufficient precipitation, while geophytes and grasses play a subordinate role. *Stipagrostis ciliata and S. obtusa* can become locally dominant in places.

Geology & Soils Permian Volksrust Formation mudrocks of the Ecca Group, Carboniferous Dwyka Group diamictites and Ceres Subgroup sandstones (Bokkeveld Group) predominate. Intrusive Jurassic Karoo dolerite dykes occur in the northwest. Sandy-loamy soils of various depths. Quartz patches are a rare phenomenon concentrated in the southern portions of the Tanqua Basin. Fc is the dominant land type, with Ag land type playing subordinate role.

Climate Winter-rainfall regime: most of the precipitation falls between May and August, while December and January are virtually precipitation-free. The region has high spatial variability of precipitation, with some rainshadows experiencing as little as 40 mm of rainfall per year (in extremely dry years). MAP varies from a low of 72 mm in the central part of the unit (Elandsvlei on the Tanqua River, 41 years of records) to 112 mm in the north of the unit (Reenen on the Wolf River, 79 years) and to 111 mm in the south of the unit (Spes Bona on the Doring River, 29 years). MAT is slightly above 17°C, but in winter the temperature can often fall below the frost mark (15 days in a year). Mean maximum and minimum monthly temperatures of 35.9°C and 5.64°C occur in January and July, respectively. See also climate diagram for SKv 5 Tanqua Karoo (Figure 5.65).

Important Taxa ([W]Western distribution limit) Succulent Shrubs: *Antimima hantamensis* (d), *Augea capensis* (d), *Gibbaeum gibbosum* (d), *Ruschia spinosa* (d), *Antimima wittebergensis*, *Aridaria noctiflora* subsp. *noctiflora*, *A. noctiflora* subsp. *straminea*, *Braunsia apiculata*, *Cephalophyllum curtophyllum*, *C. framesii*, *Crassula subaphylla*, *C. tetragona* subsp. *connivens*, *Drosanthemum delicatulum*, *D. framesii*, *D. lique*, *Euphorbia decussata*, *E. mauritanica*, *E. multiceps*, *E. rectirama*, *Hoodia gordonii*, *Leipoldtia schultzei*, *Lycium cinereum*, *Othonna*

pteronioides, *Peersia macradenia*, *Pelargonium crithmifolium*, *Phyllobolus grossus*, *P. splendens*, *Ruschia intricata*, *Salsola aphylla*, *S. namibica*, *Sarcocaulon crassicaule*, *Scopelogena bruynsii*, *Tetragonia fruticosa*, *T. robusta* var. *psiloptera*, *Tylecodon reticulatus*, *T. wallichii* subsp. *wallichii*, *Zygophyllum flexuosum*, *Z. microcarpum*. Low Shrubs: *Tripteris sinuata* (d), *Aptosimum indivisum*, *Asparagus capensis* var. *capensis*, *Berkheya spinosa*, *Chrysocoma ciliata*, *Eriocephalus africanus*, *E. ericoides*, *E. pauperrimus*, *E. spinescens*, *Euryops cuneatus*, *Galenia africana*, *G. fruticosa*, *Hermannia multiflora*, *Lessertia fruticosa*, *Limeum aethiopicum*, *Monechma spartioides*, *Pelargonium grandicalcaratum*, *Pteronia aspalatha*, *P. ciliata*, *P. erythrochaeta*, *P. glauca*, *P. intermedia*, *P. oblanceolata*, *P. pallens*, *P. scariosa*, *P. sordida*, *Rhynchosia bullata*, *Stachys cuneata*[W], *Zygophyllum microphyllum*. Semiparasitic Shrub: *Thesium lineatum*. Woody Climbers: *Asparagus fasciculatus*, *Microloma sagittatum*. Herbaceous Climber: *Cyphia comptonii*. Herbs: *Gazania lichtensteinii* (d), *Amellus microglossus*, *A. strigosus* subsp. *pseudoscabridus*, *Dicoma capensis*, *Emex australis*, *Euryops annuus*, *Hebenstretia parviflora*, *Helichrysum herniarioides*, *Lepidium africanum*, *L. desertorum*, *Lessertia pauciflora*, *Leysera tenella*, *Lotononis parviflora*, *Lyperia tristis*, *Oncosiphon grandiflorum*, *Osteospermum pinnatum*, *Pelargonium minimum*, *Plantago cafra*, *Radyera urens*, *Ursinia nana*. Geophytic Herbs: *Drimia intricata*, *Lachenalia ameliae*, *Moraea pallida*, *M. speciosa*, *Ornithogalum xanthochlorum*, *Ornithoglossum viride*, *Oxalis pes-caprae*, *Strumaria unguiculata*, *Tritonia florentiae*. Succulent Herbs: *Brownanthus vaginatus*, *Crassula muscosa*, *Duvalia caespitosa* subsp. *caespitosa*, *Mesembryanthemum excavatum*, *M. guerichianum*, *M. stenandrum*, *Psilocaulon articulatum*, *P. junceum*, *Tetragonia microptera*. Graminoids: *Stipagrostis ciliata* (d), *S. obtusa* (d), *Aristida adscensionis*, *Cladoraphis spinosa*, *Ehrharta calycina*, *Enneapogon desvauxii*, *E. scaber*, *Fingerhuthia africana*.

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Figure 5.69 SKv 5 Tanqua Karoo: Grass-rich (*Stipagrostis ciliata*) succulent shrubland dominated by *Augea capensis* (Zygophyllaceae) west of Elandsberg in the western part of the Tankwa National Park. This region is a kind of climatic anomaly since it sometimes receives as much as 30% of its annual rainfall in summer.

Biogeographically Important Taxa ([RH]Roggeveld-Hantam endemic, [S]Southern distribution limit) Low Shrubs: *Nenax cinerea*[RH], *Stachys aurea*[RH]. Herbs: *Alatoseta tenuis*[RH], *Dimorphotheca polyptera*[S], *Nemesia karroensis*[RH]. Geophytic Herbs: *Haemanthus barkerae*[RH], *Lapeirousia violacea*[RH]. Succulent Herbs: *Stapelia surrecta*[RH], *Tridentea parvipuncta subsp. truncata*[RH], *Tromotriche thudichumii*[RH].

Endemic Taxa Succulent Shrubs: *Braunsia stayneri*, *Cephalophyllum corniculatum*, *Didymaotus lapidiformis*, *Drosanthemum bellum*, *D. lignosum*, *Euphorbia gentilis* subsp. *tanquana*, *Hammeria meleagris*, *Hereroa nelii*, *H. teretifolia*, *Malephora crassa*, *Ruschia tardissima*, *Tanquana prismatica*. Geophytic Herbs: *Haemanthus tristis*, *Strumaria karoopoortensis*.

Conservation Least threatened. Target 19%. About 10% statutorily conserved in the Tankwa Karoo National Park and a further 4% in private reserves, including Inverdoorn, Zwartbosch, Jakkalsfontein, Basjanskloof, Groote Kapelsfontein, Uintjieskraal and Vaalkloof. Only a small portion of this area of low agricultural production has been transformed but due to overgrazing in some places, aliens such as *Atriplex lindleyi* subsp. *inflata* have invaded. Erosion is moderate (47%), high (36%) as well as very low (14%).

Remark 1 Tanqua (Tankwa) Karoo is one of the driest forms of the Succulent Karoo Biome, and the whole appearance of the landscape resembles desert rather than semidesert during most of the year (in extremely precipitation-poor years in particular). The eastern edge (the foot of the Roggeveld Escarpment) and southern parts of the Tanqua Karoo, are wetter and consequently more densely vegetated. The classification status of the driest parts of the Tanqua Karoo as rainshadow desert rather than semidesert (Succulent Karoo) remains open for the time being. The mapped unit nevertheless lies within the same range of MAP corresponding to some of the Succulent Karoo mapped elsewhere within the winter-rainfall region (Port Nolloth southwards to Wallekraal), but lacks the coastal fog of the latter area. The role of heavy grazing pressure in the 19th and early 20th centuries in the Tanqua Karoo needs to be evaluated in places where it is 'terribly tramped out' according to Acocks (1953).

Remark 2 Tanqua Karoo (including the extensive sheet-wash plains) is an important local centre of endemism housing two endemic genera (*Didymaotus* and *Eurystigma*) and three near-endemic genera (*Braunsia, Hammeria* and *Tanquana*)—all of the family Aizoaceae.

References Lane (1977), Jürgens (1986), Acocks (1988), Mackay (1994), Mackay & Zietsman (1996), Milton et al. (1997), Rubin (1998), Schmiedel & Mucina (2006).

SKv 6 Koedoesberge-Moordenaars Karoo

VT 26 Karroid Broken Veld (27%), VT 28 Western Mountain Karoo (27%) (Acocks 1953). LR 56 Upland Succulent Karoo (27%), LR 57 Lowland Succulent Karoo (27%) (Low & Rebelo 1996). BHU 79 Laingsberg Vygieveld (23%), BHU 75 Western Mountain Vygieveld (17%), BHU 40 Roggeveld Inland Renosterveld (15%) (Cowling & Heijnis 2001).

Distribution Western Cape and Northern Cape (smaller portion) Provinces: Koedoesberge and Pienaar se Berg low mountain ranges bordering on southern Tanqua Karoo and separated by the Klein Roggeveld Mountains from the Moordenaars Karoo

in the broad area of Laingsburg and Merweville. The unit also includes the Doesberg region east of Laingsburg and piedmonts of the Elandsberg as far as beyond the Gamkapoort Dam at Excelsior (west of Prince Albert). Altitude 500–1 250 m (most of the area at 680–1 120 m).

Vegetation & Landscape Features Slightly undulating to hilly landscape covered by low succulent scrub and dotted by scattered tall shrubs, patches of 'white' grass visible on plains, the most conspicuous dominants being dwarf shrubs of *Pteronia*, *Drosanthemum* and *Galenia*.

Geology & Soils Mudstone (mainly), shale and sandstone of the Adelaide Subgroup (Beaufort Group), accompanied by sandstone, shale and mudstone of the Permian Waterford Formation (Ecca Group) and sandstone and shale of other Ecca Group Formations as well as Dwyka Group diamictites (all of the Karoo Supergroup). This geology gives rise to shallow, skeletal soils. Region is classified as Fc land type (to a large extent), with Ib land type playing a subordinate role.

Climate Probability of rain is given for the entire year, but it is higher in winter. MAP slightly above 200 mm. There are two slight rainfall optima: one in March and another spread from May to August. MAT close to 16°C and incidence of frost relatively high (30 days). See also climate diagram for SKv 6 Koedoesberge-Moordenaars Karoo (Figure 5.65).

Important Taxa Succulent Shrubs: *Hereroa odorata* (d), *Antimima fergusoniae*, *A. maxwellii*, *A. wittebergensis*, *Aridaria noctiflora* subsp. *straminea*, *Crassula nudicaulis*, *C. rupestris* subsp. *commutata*, *Cylindrophyllum comptonii*, *Drosanthemum framesii*, *D. karrooense*, *D. lique*, *Euphorbia decussata*, *E. eustacei*, *E. mauritanica*, *Hoodia gordonii, H. grandis, Lycium oxycarpum, Manochlamys albicans*, *Peersia macradenia*, *Pelargonium crithmifolium*, *Ruschia grisea*, *R. intricata*, *Salsola aphylla*, *Sarcocaulon crassicaule*, *Sceletium rigidum*, *Tetragonia robusta* var. *psiloptera*, *Trichodiadema barbatum*, *Tylecodon reticulatus*, *T. wallichii* subsp. *wallichii*, *Zygophyllum flexuosum*. Tall Shrub: *Diospyros pallens*. Low Shrubs: *Pteronia incana* (d), *Amphiglossa tomentosa*, *Aptosimum indivisum*, *A. spinescens*, *Asparagus burchellii*, *A. capensis* var. *capensis*, *Athanasia minuta* subsp. *inermis*, *Barleria stimulans*, *Berkheya spinosa*, *Chrysocoma ciliata*, *Eriocephalus africanus*, *E. ericoides*, *E. pauperrimus*, *E. spinescens*, *Euryops lateriflorus*, *Felicia filifolia*, *F. macrorrhiza*, *F. muricata*, *F. scabrida*, *Galenia africana*, *G. fruticosa*, *Garuleum bipinnatum*, *Helichrysum lucilioides*, *Hermannia grandiflora*, *H. multiflora*, *Lessertia fruticosa*, *Limeum aethiopicum*, *Melolobium candicans*, *Menodora juncea*, *Microloma armatum*, *Monechma spartioides*, *Muraltia scoparia*, *Pelargonium hirtum*, *Pentzia incana*, *Polygala seminuda*, *Pteronia adenocarpa*, *P. ambrariifolia*, *P. empetrifolia*, *P. glauca*, *P. glomerata*, *P. pallens*, *P. scariosa*, *P. sordida*, *Rhigozum obovatum*, *Senecio haworthii*, *Tripteris sinuata*, *Zygophyllum microphyllum*, *Z. retrofractum*, *Z. spinosum*. Semiparasitic Shrub: *Thesium lineatum*. Woody Climbers: *Asparagus fasciculatus*, *A. racemosus*, *A. retrofractus*, *Microloma sagittatum*. Herbaceous Climber: *Fockea sinuata*. Semiparasitic Epiphytic Shrub: *Viscum capense*. Herbs: *Atriplex suberecta*, *Felicia bergeriana*, *Gazania jurineifolia* subsp. *scabra*, *Hermannia althaeifolia*, *H. pulverata*, *Lepidium africanum*, *L. desertorum*, *Leysera tenella*, *Pelargonium minimum*, *P. nervifolium*, *Syncarpha dregeana*, *Ursinia nana*, *Zaluzianskya inflata*, *Z. peduncularis*. Geophytic Herbs: *Drimia intricata*, *Geissorhiza karooica*, *Ixia marginifolia*, *I. rapunculoides*, *Ornithogalum adseptentrionesvergentulum*, *Oxalis obtusa*, *Romulea austinii*, *R. tortuosa* subsp. *tortuosa*, *Strumaria karooica*, *S. pubescens*, *Trachyandra thyrsoidea*. Succulent Herbs: *Astroloba foliolosa*, *A. spiralis*, *Brownanthus vaginatus*, *Crassula deceptor*, *C. muscosa*, *C. tomentosa*, *Deilanthe thudichumii*, *Haworthia marumiana* var. *archeri*, *Mesembryanthemum stenandrum*, *Pectinaria articulata, Piaranthus parvulus, Psilocaulon coriarium*, *P. junceum*, *Quaqua arenicola* subsp. *arenicola, Q. arida, Q. ramosa, Stapelia pillansii*, *S. rufa, Stapeliopsis exasperata, Tetragonia microptera*, *Tripteris aghillana* var. *integrifolia*. Parasitic Herb: *Hyobanche glabrata*. Graminoids: *Aristida adscensionis*, *A. diffusa*, *Ehrharta calycina*, *E. delicatula*, *Enneapogon scaber*, *Fingerhuthia africana*, *Karroochloa tenella*, *Pentaschistis airoides*, *Stipagrostis ciliata*, *S. obtusa*.

Biogeographically Important Taxa ([GKB]Great Karoo basin endemic, [RH]Roggeveld-Hantam endemic, [S]Southern distribution limit, [W]Western distribution limit) Succulent Shrubs: *Deilanthe peersii*[W], *Hereroa crassa*[GKB], *Pleiospilos nelii*[GKB], *Rhinephyllum graniforme*[GKB], *Ruschia crassa*[GKB], *R. perfoliata*. Low Shrubs: *Felicia lasiocarpa*[GKB], *Sericocoma pungens*[S]. Herbs: *Helichrysum cerastioides* var. *aurosicum*[W], *Ifloga molluginoides*[S]. Geophytic Herbs: *Brunsvigia comptonii*[S], *Drimia karooica*[W]. Succulent Herbs: *Aloe longistyla*[W], *Crassula hemisphaerica*[W], *Pectinaria longipes* subsp. *longipes*[RH], *Piaranthus comptus*[GKB], *Quaqua parviflora* subsp. *gracilis*[RH], *Tridentea parvipuncta* subsp. *parvipuncta*[GKB].

Endemic Taxa Succulent Shrubs: *Antimima karroidea*, *A. loganii*, *Calamophyllum teretiusculum*, *Cerochlamys gemina*, *Drosanthemum comptonii*, *Ruschia karrooica*, *Tanquana archeri*, *Trichodiadema hallii*, *Tylecodon faucium*. Low Shrub: *Pelargonium stipulaceum* subsp. *ovatostipulatum*. Semiparasitic Shrub: *Thesium marlothii*. Geophytic Herbs: *Lachenalia comptonii*, *Strumaria undulata*. Succulent Herbs: *Haworthia nortieri* var. *pehlemanniae*.

Conservation Least threatened. Target 19%. Only a very small portion enjoying statutory conservation in the Gamkapoort Nature Reserve. Transformed only to a very small extent. No serious alien plant invasions recorded. Erosion is moderate

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Figure 5.70 SKv 6 Koedoesberge-Moordenaars Karoo: Karoo shrublands with *Pteronia pallens* near Matjiesfontein (Western Cape). The Witteberge with dry quartzite fynbos are visible in the background.

(88%) and only to lesser extent high or very low.

Remark Koedoesberge-Moordenaars Karoo remains poorly researched from the vegetation-ecological point of view, despite its proximity to major university centres in the Western Cape as well as good accessibility (N1 road cuts through the region in east-west direction).

SKv 7 Robertson Karoo

VT 26 Karroid Broken Veld (77%) (Acocks 1953). Worcester-Robertson Karoo (Acocks 1979). LR 58 Little Succulent Karoo (83%) (Low & Rebelo 1996). BHU 87 Robertson Broken Veld (81%) (Cowling & Heijnis 2001). Bosjiesveld (local name).

Distribution Western Cape Province: Broad valley of the middle reaches of the Breede River around Worcester, Robertson and Ashton. Altitude 160–960 m.

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Figure 5.71 SKv 7 Robertson Karoo: Succulent shrubland in the Worcester Veld Reserve of the Western Cape Department of Agriculture, with *Aloe microstigma* (Asphodelaceae), *Ruschia caroli* (Aizoaceae) and *Galenia africana* (Aizoaceae).

Vegetation & Landscape Features Undulating flats and adjacent hills (sometimes with very steep flanks) supporting dwarf succulent shrubland to succulent thicket of medium height dominated by succulent species of *Euphorbia, Crassula* (and related genera) and vygies (*Drosanthemum* and *Ruschia* the major structural players). *Euphorbia mauritanica* (var. *corallothamnus*) is usually dominant on heuweltjies, which are an important element of the landscape and vegetation of the Robertson Karoo (Midgley & Musil 1990, Van Wyk & Smith 2001).

Geology & Soils Shale of the Devonian Ceres and Bidouw Subgroups (Bokkeveld Group, Cape Supergroup) as well as diamictite and shale of the Carboniferous Dwyka and Ecca Groups (Karoo Sequence). Jurassic Enon conglomerates occur as well. The soils are deep, red, apedal and loamy to loamy-sandy with a high clay and sodium content. Fc land type is representative of half of the region, while Fb and Ic are of lesser importance.

Climate Robertson Karoo is a semi-arid region with a mainly winter-rainfall regime and with maximum precipitation occurring in August (61 mm for Worcester, Smitheman & Perry 1990). Another slight precipitation peak is in June. MAP 125–350 mm; most of the region receiving about 300 mm. The low precipitation of this region surrounded from all sides by various Fynbos Biome vegetation units is ascribed to the rainshadow effect due to the high surrounding mountain ranges. MAT is above 16°C. Summer temperatures are high and in January vary from 30–40°C (an average of 34.5°C in February was recorded for Worcester). Occasional northwestern berg winds may intensify the heat. Winter nights might experience light frost—7 days a year on average. See also climate diagram for SKv 7 Robertson Karoo (Figure 5.65).

Important Taxa Succulent Shrubs: *Aloe microstigma* (d), *Cotyledon orbiculata* var. *orbiculata* (d), *Crassula rupestris* subsp. *commutata* (d), *Euphorbia burmannii* (d), *E. mauritanica* (d), *Lycium oxycarpum* (d), *Ruschia caroli* (d), *R. cymosa* (d), *Senecio junceus* (d), *Tylecodon paniculatus* (d), *Adromischus filicaulis* subsp. *marlothii*, *A. maculatus*, *A. mammillaris*, *Antimima fergusoniae*, *A. peersii*, *Cephalophyllum curtophyllum*, *C. purpureo-album*, *Crassula atropurpurea* var. *anomala*, *C. cultrata*, *C. nudicaulis*, *C. subaphylla*, *C. tetragona* subsp. *tetragona*, *Drosanthemum micans*, *D. striatum*, *Hereroa tenuifolia*, *Lampranthus dependens*, *L. haworthii*, *Leipoldtia schultzei*, *Pelargonium alternans*, *Phyllobolus grossus*, *P. nitidus*, *P. splendens*, *Ruschia multiflora*, *Tetragonia fruticosa*. Tall Shrubs: *Euclea undulata* (d), *Lebeckia cytisoides*. Low Shrubs: *Pentzia incana* (d), *Pteronia incana* (d), *Amphithalea spinosa*, *Anginon difforme*, *Asparagus burchellii*, *Ballota africana*, *Carissa haematocarpa*, *Chrysocoma ciliata*, *Elytropappus rhinocerotis*, *Eriocephalus africanus*, *E. ericoides*, *Felicia filifolia*, *Galenia africana*, *G. fruticosa*, *Helichrysum hamulosum*, *Hirpicium integrifolium*, *Microdon polygaloides*, *Oedera genistifolia*, *Pelargonium ramosissimum*, *Prenia englishiae*, *Pteronia fasciculata*, *P. paniculata*, *Selago ramosissima*, *Wahlenbergia thunbergiana*. Semiparasitic Shrub: *Thesium patulum*. Woody Succulent Climber: *Sarcostemma viminale*. Geophytic Herbs: *Albuca maxima* (d), *Drimia altissima* (d), *D. capensis* (d), *Kniphofia sarmentosa*, *Moraea viscaria*, *Oxalis pes-caprae*. Succulent Herbs: *Psilocaulon junceum* (d), *Crassula capitella* subsp. *thyrsiflora*, *C. cotyledonis*, *C. muscosa*, *Duvalia elegans*, *Gasteria disticha*, *Haworthia arachnoidea*, *Mesembryanthemum longistylum*, *Psilocaulon bicorne*, *Senecio radicans, Stapeliopsis breviloba*. Graminoids: *Ehrharta calycina*, *E. delicatula*, *E. longiflora*, *E. ramosa* subsp. *aphylla*.

Biogeographically Important Taxa ([S]Southern distribution limit, [W]Western distribution limit) Low Shrub: *Pteronia flexicaulis*[W]. Herbaceous Climber: *Cyphia angustifolia*[S]. Herb: *Arctotis cuprea*[S].

Endemic Taxa Succulent Shrubs: *Drosanthemum speciosum* (d), *Antimima biformis*, *A. hamatilis*, *A. leipoldtii*, *Brianhuntleya intrusa*, *Delosperma macrostigma*, *Drosanthemum anomalum*, *D. laxum*, *D. leptum*, *D. papillatum*, *D. pickhardii*, *D. pulchrum*, *D. thudichumii*, *D. tuberculiferum*, *D. worcesterense*, *Euphorbia nesemannii*, *Phyllobolus caudatus*, *Ruschia subteres*, *Sceletium varians*, *Stayneria neilii*. Low Shrubs: *Aizoon karooicum*, *Aspalathus ferox, Polhillia obsoleta*. Herbaceous Succulent Climbers: *Ceropegia fimbriata* subsp. *connivens*, *C. occulta*. Herb: *Pelargonium oxaloides*. Geophytic Herbs: *Eriospermum bowieanum*, *Pelargonium violiflorum*. Succulent Herbs: *Astroloba rubriflora*, *Conophytum ficiforme*, *Crassula simulans*, *Haworthia herbacea* var. *herbacea*, *H. maculata*, *H. maraisii*, *H. pubescens*, *H. reticulata*, *Stapelia paniculata* subsp. *scitula*.

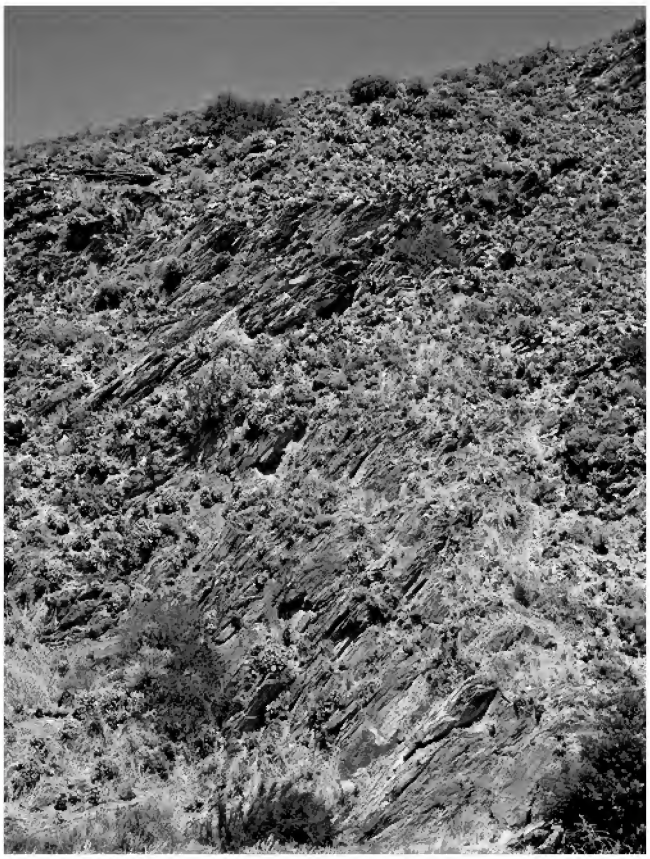

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Figure 5.72 SKv 7 Robertson Karoo: Steep shale slopes with *Tylecodon paniculatus*, *Aloe microstigma* and numerous *Crassula* species at De Wet wine cellar near Worcester (Western Cape).

Conservation Least threatened. Target 16%. Small area statutorily conserved in the Vrolijkheid Nature Reserve as well as on the premises of the Karoo Desert National Botanical Garden in Worcester (Oliver 2000) and in the Department of Agriculture Field Reserve (Olivier 1979). Marginal patches of the Robertson Karoo are under protection of private reserves such as Matroosberg, Drooge Riviers Berg, Langeberg-wes, Riviersonderend and Doornkloof. About 16% has been transformed by urban development as well as by cultivation: vineyards and orchards. Alien plant invasions can be a problem in places. The pressure of natural erosion processes is moderate (45%) to both high (24%) and low (22%).

Remark The region is the heart of the Worcester-Robertson Karoo Centre of Endemism (Van Wyk & Smith 2001). Two genera are endemic to this unit—*Stayneria* and *Brianhuntleya* (Van Wyk & Smith 2001, Chesselet et al. 2003). *Drosanthemum* and *Haworthia* show a high concentration of local endemics.

References Olivier (1966, 1979), Joubert (1968), Acocks (1979, 1988), Boshoff (1989), Midgley & Musil (1990), Smitheman & Perry (1990), Oliver (2000), Cowling & Heijnis (2001), Van Wyk & Smith (2001), Chesselet et al. (2003).

SKv 8 Western Little Karoo

VT 26 Karroid Broken Veld (80%) (Acocks 1953). Ladismith Karoo (Acocks 1979). LR 58 Little Succulent Karoo (85%) (Low & Rebelo 1996). BHU 88 Little Karoo Broken Veld (77%) (Cowling & Heijnis 2001).

Distribution Western Cape Province: The unit covers most of the western basin of the Little Karoo from the confluence of the Groot and Gouritz Rivers in the west as far as Anysberg by surrounding this mountain range and also extending along the northern flanks of the Klein Swartberg. Two larger patches of the Western Little Karoo are found immediately to the east and south of Touws River and one small isolated patch fringes the Langeberg Mountains in the Montagu area. Altitude 160–1 060 m (most of the area at 300–860 m).

Vegetation & Landscape Features Flat or slightly undulating landscapes dominated by a mosaic of Karoo shrublands of low and medium height encompassing (as dominants) both non-succulent (*Chrysocoma, Pentzia, Pteronia, Rhigozum, Tripteris*) as well as succulent (*Crassula, Euphorbia, Ruschia, Tylecodon*) shrubs.

Geology & Soils Sandstone and shale of the Devonian Bidouw and Ceres Subgroups (both belonging to Bokkeveld Group, Cape Supergroup), Devonian sandstone of the Witteberg Group and Silurian sandstone of the Nardouw Subgroup (Table Mountain Group, Cape Supergroup), supporting deep, loamy-sandy (mainly) soils. The region has been classified as Fc land type.

Climate Western Little Karoo has a multimodal precipitation regime with major peaks in May and August and minor ones in March and November. December to January is markedly drier—a hint towards a slight inclination of the local climate towards a winter-rainfall pattern. MAP is around 230 mm (semidesert). MAT 16°C. On average 14 frost days per year. See also climate diagram for SKv 8 Western Little Karoo (Figure 5.65).

Important Taxa Small Tree: *Pappea capensis*. Succulent Shrubs: *Crassula rupestris* subsp. *commutata* (d), *Drosanthemum wittebergense* (d), *Euphorbia mauritanica* (d), *Hereroa odorata* (d), *Ruschia cymosa* (d), *R. spinosa* (d), *Tylecodon paniculatus* (d), *T. wallichii* subsp. *wallichii* (d), *Adromischus filicaulis* subsp. *marlothii*, *A. mammillaris*, *Aridaria noctiflora* subsp. *noctiflora*, *Augea capensis*, *Braunsia geminata*, *Cotyledon cuneata*, *C. orbiculata* var. *orbiculata*, *Crassula cultrata*, *C. ovata*, *C. rupestris* subsp. *rupestris*, *C. subaphylla*, *Drosanthemum chrysum*, *D. lique*, *Euphorbia brachiata*, *E. mammillaris*, *E. multiceps*, *E. mundii*, *E. stolonifera*, *Gibbaeum nuciforme*, *Leipoldtia schultzei*, *Lycium oxycarpum*, *Othonna carnosa*, *Phyllobolus nitidus*, *P. splendens*, *Ruschia archeri*, *R. intricata*, *R. multiflora*, *Salsola aphylla*, *Sarcocaulon patersonii*, *Sceletium rigidum*, *Smicrostigma viride*, *Tetragonia fruticosa*, *T. robusta* var. *psiloptera*, *Tylecodon cacalioides*. Tall Shrubs: *Euclea undulata*, *Putterlickia pyracantha*. Low Shrubs: *Chrysocoma ciliata* (d), *Eriocephalus ericoides* (d), *Felicia filifolia* (d), *F. muricata* (d), *Galenia africana* (d), *Monechma spartioides* (d), *Pentzia incana* (d), *Pteronia incana* (d), *P. pallens* (d), *Rhigozum obovatum* (d), *Rosenia humilis* (d), *Tripteris sinuata* (d), *Amphithalea spinosa*, *Aptosimum procumbens*, *Argyrolobium collinum*, *Asparagus burchellii*, *A. capensis* var. *capensis*, *A. krebsianus*, *A. mucronatus*, *Barleria pungens*, *Berkheya spinosa*, *Carissa haematocarpa*, *Elytropappus rhinocerotis*, *Eriocephalus africanus*, *E. purpureus*, *Felicia macrorrhiza*, *F. ovata*, *F. whitehillensis*, *Galenia fruticosa*, *G. secunda*, *Garuleum latifolium*, *Gnidia deserticola*, *Helichrysum asperum* var. *albidulum*, *H. rosum*, *H. simulans*, *H. zeyheri*, *Hermannia filifolia* var. *grandicalyx*, *H. multiflora*, *Hirpicium integrifolium*, *Indigofera heterophylla*, *Justicia cuneata* subsp. *cuneata*, *Lessertia fruticosa*, *Limeum aethiopicum*, *Macledium spinosum*, *Nenax microphylla*, *Oedera squarrosa*, *Osteospermum microphyllum*, *Pegolettia baccaridifolia*, *Pentzia elegans*, *P. lanata*, *P. spinescens*, *Phymaspermum aciculare*, *Plumbago tristis*, *Polygala asbestina*, *Pteronia adenocarpa*, *P. empetrifolia*, *P. fasciculata*, *P. flexicaulis*, *P. glauca*, *P. membranacea*, *P. oblanceolata*, *P. paniculata*, *P. sordida*, *P. succulenta*, *Rosenia oppositifolia*, *Selago geniculata*, *Sericocoma avolans*, *Zygophyllum microphyllum*, *Z. spinosum*. Semiparasitic Shrub: *Thesium lineatum*. Woody Climbers: *Asparagus racemosus*, *A. retrofractus*, *Cissampelos capensis*, *Microloma sagit-*

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Figure 5.73 SKv 8 Western Little Karoo: Succulent shrubland with abundant *Berkheya cuneata* (Asteraceae), a regional Little Karoo endemic, near Barrydale (Western Cape).

tatum. Herbaceous Succulent Climber: *Othonna amplexifolia*. Semiparasitic Epiphytic Shrub: *Viscum rotundifolium*. Herbs: *Cineraria platycarpa* (d), *Cotula bipinnata* (d), *Diascia parviflora* (d), *Foveolina dichotoma* (d), *Heliophila pectinata* (d), *Plantago cafra* (d), *Amellus microglossus*, *Galenia papulosa*, *Heliophila amplexicaulis*, *Hermannia pulverata*, *Leysera gnaphalodes*, *Lotononis pungens*. Geophytic Herbs: *Albuca maxima* (d), *Oxalis obtusa* (d), *O. pes-caprae* (d), *Xenoscapa fistulosa* (d), *Drimia intricata*, *Empodium plicatum*, *Geissorhiza karooica*, *Lachenalia ameliae*, *Oxalis convexula*. Succulent Herbs: *Crassula lanceolata* (d), *C. orbicularis* (d), *Psilocaulon articulatum* (d), *P. junceum* (d), *Aloe variegata*, *Astroloba foliolosa*, *Crassula muscosa*, *Othonna auriculifolia*, *Psilocaulon coriarium*, *Senecio radicans*, *Stapelia engleriana*, *S. pillansii*, *S. rufa*, *Stapeliopsis saxatilis*, *Tetragonia microptera*, *Tridentea gemmiflora*. Graminoids: *Ehrharta delicatula* (d), *Stipagrostis obtusa* (d), *Digitaria argyrograpta*, *Ehrharta calycina*, *E. erecta*, *Enneapogon scaber*.

Biogeographically Important Taxa ([LK]Little Karoo endemic, [S]Southern distribution limit, [E]Eastern distribution limit, [W]Western distribution limit) Succulent Shrubs: *Drosanthemum delicatulum*[LK] (d), *Glottiphyllum depressum*[LK], *Tetragonia glauca*[S]. Tall Shrub: *Freylinia densiflora*[LK]. Low Shrubs: *Asparagus glaucus*[W], *Barleria stimulans*[W], *Berkheya cuneata*[LK], *Eriocephalus pauperrimus*[S], *Euryops imbricatus*[S], *Polygala empetrifolia*[LK], *P. uncinata*[LK], *Pteronia glomerata*[S], *Rosenia glandulosa*[S]. Herb: *Alonsoa peduncularis*[LK]. Geophytic Herb: *Freesia speciosa*[LK]. Succulent Herb: *Duvalia parviflora*[LK]. Graminoid: *Stipagrostis anomala*[S].

Endemic Taxa Succulent Shrubs: *Cotyledon tomentosa* subsp. *ladismithiensis*, *Crassula atropurpurea* var. *muirii*, *Drosanthemum bicolor*, *D. crassum*, *D. globosum*, *D. splendens*, *Gibbaeum nebrownii*, *Glottiphyllum cruciatum*, *G. suave*, *Lampranthus egregius*, *Octopoma octojuge*, *O. quadrisepalum*. Low Shrub: *Dicoma fruticosa*. Herb: *Diascia hexensis*. Geophytic Herb: *Ornithogalum synadelphicum*. Succulent Herb: *Haworthia pulchella*.

Conservation Least threatened. Target 16%. About 4% of the area is statutorily conserved in Anysberg and Dornkloof Nature Reserves and Eyerpoort (private reserve). About 3% has been transformed by cultivation. Alien *Acacia cyclops* and *A. saligna* pose a threat to the vegetation locally. Invasive *Atriplex lindleyi* subsp. *inflata* is a serious local problem for grazing. Erosion is high (54%), moderate (19%) and very low (15%).

Remark This unit is characterised by a high species density of *Asparagus, Crassula, Diascia, Dicoma, Euphorbia* and *Pteronia*, a high number of endemic species in *Drosanthemum* as well as the occurrence of one endemic genus—*Octopoma* (Aizoaceae).

References Muir (1929), Acocks (1953, 1988), Vlok (2002), Schmiedel & Mucina (2006).

SKv 9 Western Gwarrieveld

VT 25 Succulent Mountain Scrub (Spekboomveld) (50%) (Acocks 1953). LR 8 Spekboom Succulent Thicket (46%), LR 58 Little Succulent Karoo (45%) (Low & Rebelo 1996). BHU 97 Spekboom Xeric Succulent Thicket (47%), BHU 88 Little Karoo Broken Veld (46%) (Cowling & Heijnis 2001). STEP Vanwyksdorp Gwarrieveld (97%) (Vlok & Euston-Brown 2002).

Distribution Western Cape Province: Region of the western Little Karoo basin covering the northern, western and southern

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Figure 5.74 SKv 9 Western Gwarrieveld: Undulating landscape of Noukloof Nature Reserve near Ladismith (Western Cape) supporting gwarrieveld involving low succulent shrublands on the slopes (with high dominance of *Pteronia incana*) with scattered tall shrubs and small trees of *Pappea capensis* and *Euclea undulata*. Linear patches of AZi 8 Muscadel Riviere are found on alluvial terraces on flat bottoms of valleys.

piedmonts of the Rooiberg Mountains roughly from Ladismith to Vanwyksdorp. The area north of the confluence of the Groot and Gouritz Rivers is classified as this unit as well. Altitude 120–800 m (most of area at 200–600 m).

Vegetation & Landscape Features Low hilly country supporting low Succulent Karoo shrublands, peppered with solitary trees and tall shrub groups (*Euclea, Lycium, Pappea, Rhus*).

Geology & Soils Sandstones, siltstones and mudstones of the Devonian Ceres and Bidouw Subgroups (both belonging to Bokkeveld Group, Cape Supergroup) as well as (to lesser extent) sandstones of the Silurian Nardouw Subgroup (member of the Table Mountain Group, Cape Supergroup) supporting loamy-clayey soils. Fc is the overwhelmingly dominant land type of the region.

Climate The overall precipitation regime of this unit is similar to that of SKv 8 Western Little Karoo, but the Gwarrieveld is wetter (MAP 260 mm) and warmer (MAT slightly above 17°C) and it has only 8 frost days a year. See also climate diagram for SKv 9 Western Gwarrieveld (Figure 5.65).

Important Taxa Small Trees: *Pappea capensis* (d), *Schotia afra* var. *afra*. Succulent Shrubs: *Aloe microstigma* (d), *Adromischus mammillaris*, *Cotyledon orbiculata* var. *orbiculata*, *Crassula arborescens* subsp. *arborescens*, *C. rupestris* subsp. *commutata*, *C. subaphylla*, *Drosanthemum framesii*, *D. lique*, *Euphorbia mauritanica*, *E. pillansii*, *E. stolonifera*, *Galenia sarcophylla*, *Leipoldtia schultzei*, *Lycium cinereum*, *Othonna carnosa*, *Phyllobolus splendens*, *Ruschia spinosa*, *Salsola aphylla*, *Sarcocaulon burmanni*, *Sceletium rigidum*, *Senecio articulatus*, *Tetragonia fruticosa*, *T. glauca*, *T. robusta* var. *psiloptera*, *T. spicata*, *Tylecodon paniculatus*, *T. reticulatus*, *Zygophyllum pygmaeum*. Tall Shrubs: *Euclea undulata* (d), *Cadaba aphylla*, *Nymania capensis*, *Putterlickia pyracantha*, *Rhus undulata*. Low Shrubs: *Eriocephalus ericoides* (d), *Pentzia incana* (d), *Pteronia incana* (d), *Aptosimum indivisum*, *Asparagus capensis* var. *capensis*, *A. mucronatus*, *A. recurvispinus*, *Ballota africana*, *Bassia salsoloides*, *Blepharis capensis*, *Carissa haematocarpa*, *Chrysocoma ciliata*, *Elytropappus rhinocerotis*, *Felicia filifolia*, *F. muricata*, *Galenia africana*, *G. fruticosa*, *Garuleum bipinnatum*, *G. latifolium*, *Helichrysum excisum*, *H. zeyheri*, *Hermannia filifolia* var. *grandicalyx*, *H. multiflora*, *Limeum aethiopicum*, *Microdon polygaloides*, *Monechma spartioides*, *Pentzia dentata*, *Polygala asbestina*, *P. myrtifolia*, *P. teretifolia*, *Pteronia flexicaulis*, *P. glauca*, *P. membranacea*, *P. oblanceolata*, *P. pallens*, *Rhigozum obovatum*, *Selago acocksii*, *Sutera subnuda*, *Tripteris sinuata*, *Zygophyllum microphyllum*. Woody Succulent Climber: *Crassula perforata*. Woody Climbers: *Asparagus aethiopicus*, *A. racemosus*. Herbaceous Succulent Climbers: *Crassula roggeveldii*, *Othonna amplexifolia*. Herbs: *Amellus microglossus*, *Cineraria platycarpa*, *Cotula bipinnata*, *Diascia parviflora*, *Dimorphotheca nudicaulis* var. *graminifolia*, *Foveolina dichotoma*, *Galenia papulosa*, *Gazania jurineifolia* subsp. *scabra*, *Heliophila crithmifolia*, *H. pectinata*, *Hemimeris racemosa*, *Hermannia pulverata*, *Leidesia procumbens*, *Lepidium africanum*, *L. desertorum*, *Rhynchopsidium sessiliflorum*, *Sisymbrium capense*, *Trichogyne paronychioides*. Geophytic Herbs: *Bulbine frutescens*, *Chlorophytum crispum*, *Drimia intricata*, *Freesia refracta*, *Hesperantha acuta*, *Melasphaerula ramosa*, *Moraea polystachya*, *Oxalis obtusa*, *O. pes-caprae*. Succulent Herbs: *Aloe variegata*, *Crassula capitella* subsp. *capitella*, *C. expansa* subsp. *expansa*, *C. muscosa*, *C. orbicularis*, *Haworthia viscosa*, *Mesembryanthemum guerichianum*, *Psilocaulon articulatum*, *P. junceum*, *Senecio radicans*. Graminoids: *Ehrharta calycina*, *E. erecta*, *E. longiflora*, *Enneapogon scaber*, *Fingerhuthia africana*, *Pentaschistis airoides*, *Tribolium hispidum*.

Biogeographically Important Taxa (all Little Karoo endemics) Succulent Shrubs: *Drosanthemum delicatulum*, *Pelargonium curviandrum*. Tall Shrub: *Calpurnia villosa* var. *intrusa*. Low Shrubs: *Berkheya cuneata*, *Polygala empetrifolia*. Succulent Herbs: *Haworthia blackburniae* var. *blackburniae*, *Huernia praestans*.

Conservation Least threatened. Target 16%. Some 3% statutorily conserved in Ladismith-Klein Karoo Nature Reserve and an additional 1% is under less formal protection in private nature reserves such as Taayskloof, Buffelspoort, Rooiberg and Klein Swartberg. Only about 2% has so far been transformed by cultivation, but overgrazing (by sheep) is not uncommon. Aliens, *Acacia cyclops* and *A. saligna*, can be seen as a threat in places. Erosion is high (42%), very low (38%) and moderate (14%).

References Muir (1929), Acocks (1988).

SKv 10 Little Karoo Quartz Vygieveld

VT 26 Karroid Broken Veld (99%) (Acocks 1953). LR 58 Little Succulent Karoo (71%) (Low & Rebelo 1996). BHU 88 Little Karoo Broken Veld (66%) (Cowling & Heijnis 2001).

Distribution Western Cape Province: Especially in the western regions of the Little Karoo, bordered by the Witteberg and Swartberg Mountains from the north and the Riviersonderend, Langeberg and Outeniqua Mountains from the south, between the Koegaberge in the west and Oudtshoorn in the east. The largest patches are found at the northern foothills of the Langeberg Mountains, between Barrydale and Muiskraal. Altitude 220–720 m.

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Figure 5.75 SKv 10 Little Karoo Quartz Vygieveld: Quartz fields near Groot Phesantefontein near Muiskraal in the Western Little Karoo with an undescribed dominant succulent *Sarcocornia* species and *Gibbaeum album* ('stone plant').

Vegetation & Landscape Features Flat and slightly undulating plains covered by open, low vegetation dominated by fruticose or compact leaf-succulent dwarf members of Aizoaceae (*Gibbaeum*), Crassulaceae and Euphorbiaceae, accompanied by nonsucculent asteraceous shrubs and dwarf shrubs.

Geology & Soils Loamy-sandy, shallow to moderately deep, slightly alkaline soils, mainly derived from micaceous sandy shales and mudstones of the Devonian Ceres and Bidouw Subgroups (both belonging to Bokkeveld Group, Cape Supergroup) as well as (to lesser extent) sandstones of the Silurian Nardouw Subgroup (member of the Table Mountain Group, Cape Supergroup). The soil surface is densely covered with characteristic quartz gravel and rubble (derived from weathered quartz veins accompanying the shales). Fc is the overwhelmingly dominant land type.

Climate MAP of 220 mm is multimodal and distributed in similar fashion as in SKv 8 Western Little Karoo and SKv 9 Western Gwarrieveld. A tendency towards winter-rainfall regime can be detected in the western part of the distribution area of the quartz fields, while the influence of summer rainfall increases in an eastwards direction. MAT 16.5°C, high temperatures can be reached in summer (well above 30°C). Winters are mild, with occurrence of occasional light night frost (7 days a year). See also climate diagram for SKv 10 Little Karoo Quartz Vygieveld (Figure 5.65).

Important Taxa Succulent Shrubs: *Gibbaeum gibbosum* (d), *Hereroa tenuifolia* (d), *Sarcocornia* sp. nov. (*Mucina 160601/10* STEU) (d), *Adromischus filicaulis* subsp. *marlothii*, *Antegibbaeum fissoides*, *Caulipsolon rapaceum*, *Drosanthemum delicatulum*, *Tetragonia robusta* var. *psiloptera*. Low Shrubs: *Pteronia pallens* (d), *Chrysocoma ciliata*, *Macledium relhanioides*, *Pteronia empetrifolia*, *P. succulenta*, *P. viscosa*, *Tripteris sinuata*. Succulent Herbs: *Anacampseros papyracea*, *Crassula columnaris* subsp. *columnaris*, *C. deltoidea*, *C. pyramidalis, Psilocaulon articulatum*.

Biogeographically Important Taxon (Little Karoo endemic) Succulent Shrub: *Gibbaeum nuciforme* (d).

Endemic Taxa Succulent Shrubs: *Gibbaeum album* (d), *G. dispar* (d), *G. heathii* (d), *G. petrense* (d), *G. pubescens* (d), *Muiria hortenseae* (d), *Zeuktophyllum suppositum* (d), *Cerochlamys pachyphylla*, *Drosanthemum albiflorum*, *Euphorbia susannae*, *Gibbaeum pachypodium*, *G. pilosulum*, *G. shandii*, *Hereroa muirii*, *Rhinephyllum muirii*, *Salsola verdoorniae*, *Zeuktophyllum calycinum*. Succulent Herbs: *Conophytum joubertii*, *C. piluliforme*, *Crassula congesta*, *Quaqua ramosa*.

Conservation Target 16%. Only about 2% statutorily conserved in the Anysberg Nature Reserve, but a further 7% finds some level of protection in the Eyerpoort Private Nature Reserve. Almost 8% of the area has experienced transformation, but most of the quartz-field communities of the Little Karoo are exposed to increasing pressure from the local rangeland farming with sheep, goats, game and ostrich. Erosion is high (84%) or moderate (12%). The level and extent of threats of particular quartz vygieveld communities have been analysed in great detail by Schmiedel & Mucina (2006).

Remark Quartz fields in the arid regions of southern Africa represent edaphically defined special habitats, which house distinct vegetation units typically dominated by a number of habitat endemics. In different regions, the quartz fields are inhabited by similar plant growth forms of distantly related lineages (mainly Aizoaceae). This phenomenon has been interpreted as convergent evolution in adaptation to special habitat conditions. The total cover of the quartz field vegetation (10–20%) is typically significantly lower than that of the surrounding vegetation (20–40%). Geophytic *Caulipsolon rapaceum*, unpalatable *Pteronia pallens* as well as alien *Atriplex lindleyi* subsp. *inflata* are indicators of disturbance by overgrazing or trampling. High erosion pressure has presumably been a typical (and natural) feature of the quartz-field habitats.

References Schmiedel & Jürgens (1999, 2002, 2004), Schmiedel (2002a, b, 2004), Vlok (2002), Schmiedel & Mucina (2006).

SKv 11 Eastern Little Karoo

VT 25 Succulent Mountain Scrub (Spekboomveld) (51%) (Acocks 1953). LR 8 Spekboom Succulent Thicket (43%), LR 58 Little Succulent Karoo (36%) (Low & Rebelo 1996). BHU 97 Spekboom Xeric Succulent Thicket (43%), BHU 89 Oudtshoorn Broken Veld (34%) (Cowling & Heijnis 2001). STEP Blossoms Karroid Thicket (33%), STEP Calitzdorp Karroid Thicket (21%) (Vlok & Euston-Brown 2002).

Distribution Western Cape Province: Eastern basin of the Little Karoo from Calitzdorp in the west as far as Oudtshoorn in the east. The unit continues in a series of narrow belts (alternating with the Willowmore Gwarrieveld unit from the surrounds of Dysselsdorp as far west as the N2 road. A narrow belt of the Eastern Little Karoo fringes the southern flanks of the Kammanassie Mountains along the Kammanassie River as far west as Uniondale. Altitude 320–960 (most of area at 320–550 m).

Vegetation & Landscape Features Irregularly flat plains and undulating piedmont hills covered by dense succulent shrubland dominated by Aizoaceae (*Ruschia, Drosanthemum*) and Crassulaceae (*Cotyledon, Crassula, Tylecodon,*) and nonsucculent, mainly shrubs such as *Nymania, Pteronia* and *Rhus*. The spring displays of annual and geophyte flora are spectacular in years with good rain.

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Figure 5.76 SKv 11 Eastern Little Karoo: Succulent shrubland with *Tylecodon cacalioides* south of Oudtshoorn in the Little Karoo (Western Cape).

Geology & Soils Fossiliferous shales, mudstones and siltstones of the Devonian Bokkeveld Group (Ceres and Traka Subgroups). Also present are mudstones and sandstones as well as subordinate shale of the Kirkwood Formation together with conglomerates of the Enon Formation (both of the Mesozoic Uitenhage Group). Soils developing over these substrates are of varied structure and texture, but mainly loamy-silty and deep in places. Ag and Fc land types are equally important (and dominant) in the region.

Climate Aseasonal rainfall (MAP almost 290 mm) with slight optimum in March and pronounced dip in December to January (summer). MAT is about 17°C and frost occurs only 9 days per year. See also climate diagram for SKv 11 Eastern Little Karoo (Figure 5.65).

Important Taxa Succulent Tree: *Aloe ferox*. Succulent Shrubs: *Augea capensis* (d), *Leipoldtia schultzei* (d), *Tylecodon cacalioides* (d), *Cotyledon orbiculata* var. *orbiculata*, *C. tomentosa* subsp. *tomentosa*, *Crassula cultrata*, *C. nudicaulis*, *C. ovata*, *C. rupestris* subsp. *commutata*, *Drosanthemum lique*, *Euphorbia colliculina*, *E. mauritanica*, *Glottiphyllum carnosum*, *G. linguiforme*, *Lycium oxycarpum*, *Marlothistella stenophylla*, *M. uniondalensis*, *Othonna carnosa*, *Phyllobolus splendens*, *Pleiospilos compactus* subsp. *compactus*, *Ruschia grisea*, *R. spinosa*, *Smicrostigma viride*, *Tetragonia fruticosa*, *T. robusta* var. *psiloptera*, *Trichodiadema burgeri*, *Tylecodon paniculatus*, *T. wallichii* subsp. *wallichii*, *Zygophyllum morgsana*. Tall Shrubs: *Cadaba aphylla*, *Euclea undulata*, *Nymania capensis*, *Putterlickia pyracantha*, *Rhus lucida*, *R. pallens*. Low Shrubs: *Pentzia incana* (d), *Pteronia incana* (d), *Rhigozum obovatum* (d), *Aptosimum elongatum*, *Asparagus burchellii*, *A. glaucus*, *A. recurvispinus*, *Berkheya spinosa*, *Carissa haematocarpa*, *Chrysocoma ciliata*, *Elytropappus rhinocerotis*, *Eriocephalus ericoides*, *Felicia muricata*, *Galenia africana*, *G. fruticosa*, *G. secunda*, *Garuleum latifolium*, *Helichrysum asperum* var. *albidulum*, *H. simulans*, *Hermannia filifolia* var. *grandicalyx*, *Hirpicium alienatum*, *Limeum aethiopicum*, *Macledium relhanioides*, *Oedera genistifolia*, *Pegolettia baccaridifolia*, *Polygala myrtifolia*, *Pteronia flexicaulis*, *P. glauca*, *P. pallens*, *Rosenia humilis*, *Tripteris sinuata*, *Zygophyllum microphyllum*, *Z. spinosum*. Semiparasitic Shrub: *Thesium lineatum*. Woody Succulent Climbers: *Crassula perforata*, *Sarcostemma viminale*. Woody Climbers: *Asparagus racemosus*, *A. retrofractus*, *Cissampelos capensis*. Herbaceous Succulent Climber: *Othonna amplexifolia*. Herbaceous Climber: *Fockea sinuata*. Semiparasitic Epiphytic Shrub: *Viscum rotundifolium*. Herbs: *Atriplex semibaccata* var. *appendiculata*, *Chamaesyce inaequilatera*, *Galenia papulosa*, *Galium tomentosum*, *Helichrysum tinctum*, *Hermannia althaeifolia*, *H. pulverata*, *Indigofera porrecta* var. *bicolor*, *Lepidium africanum*, *L. desertorum*, *Sutera caerulea*, *Tribulus terrestris*. Geophytic Herbs: *Chlorophytum crispum*, *Drimia intricata*, *Empodium plicatum*, *Freesia refracta*, *F. verrucosa*. Succulent Herbs: *Psilocaulon junceum* (d), *Astroloba spiralis*, *Crassula capitella* subsp. *capitella*, *C. expansa* subsp. *expansa*, *C. muscosa*, *Gasteria brachyphylla*, *Haworthia truncata*, *Mesembryanthemum guerichianum*, *Psilocaulon articulatum*, *Senecio ficoides*, *Tetragonia microptera*. Graminoids: *Cynodon dactylon*, *C. incompletus*, *Ehrharta calycina*, *Pentaschistis airoides*.

Biogeographically Important Taxa (all Little Karoo endemics) Succulent Shrubs: *Carruanthus ringens*, *Gibbaeum nuciforme*, *Glottiphyllum depressum*. Low Shrub: *Berkheya cuneata*. Succulent Herb: *Crassula tecta*.

Endemic Taxa Succulent Shrubs: *Antimima brevicollis*, *Delosperma calitzdorpense*, *Drosanthemum duplessiae*, *Machairophyllum brevifolium*, *Pleiospilos compactus* subsp. *fergusoniae*, *Tanquana hilmarii*, *Tylecodon leucothrix*. Geophytic Herbs: *Albuca thermarum*, *Eriospermum crispum*, *Syringodea derustensis*. Succulent Herb: *Crassula badspoortense*.

Conservation Least threatened. Target 16%. Only very small portions are statutorily conserved in the Kammanassie and Swartberg East Nature Reserves and in some private reserves (Ortmansgat, Greylands). Much of the area has been transformed either by cultivation or dam-building (Kammanassie Dam, Stompdrift Dam). Local overgrazing can promote invasion of alien *Atriplex lindleyi* subsp. *inflata* and aggravate erosion, which is ranked moderate (76%) and high (13%).

References Van Wyk & Smith (2001), Vlok & Euston-Brown (2002), Van Jaarsveld & Van Wyk (2003), Vlok et al. (2003), Cleaver et al. (2005).

SKv 12 Willowmore Gwarrieveld

VT 26 Karroid Broken Veld (54%) (Acocks 1953). LR 54 Central Lower Nama Karoo (69%) (Low & Rebelo 1996). BHU 92 Steytlerville Broken Veld (61%) (Cowling & Heijnis 2001). STEP Gamtoos Gwarrieveld (52%) (Vlok & Euston-Brown 2002).

Distribution Eastern (and to smaller extent) and also Western Cape Provinces: Broad valley between the Droëkloofberge (near Klaarstroom) and Groot Swartberg Mountains and continuing as broad band from Willowmore, along the northern piedmonts of the Baviaanskloof Mountains as far east as Kleinpoort (south of Klein Winterhoek Mountains). A smaller area of this unit also occurs south of the Groot Swartberg, in the valley of the Eastern Little Karoo between Dysselsdorp in the west and the N9 road in the east. Altitude 460–1 140 m (most of area at 480–900 m).

Vegetation & Landscape Features Slightly undulating landscape composed of extensive flats and a series of low hills. Dwarf succulent shrubland punctuated by scattered thicket clumps of medium height and solitary small trees (*Pappea capensis, Euclea undulata*). There is a strong north-south aspect effect, with the cooler southern slopes supporting patches of renosterveld (*Elytropappus rhinocerotis* dominant), especially where the soils are a sandy loam. *Portulacaria afra* can still be encountered on northern slopes.

Geology & Soils Shale, sandstone and siltstone of the Bokkeveld Group (mostly the Traka Subgroup as well as the Ceres Subgroup, both Devonian) as well as quartzites of the slightly younger Witteberg Group (all of the Cape Supergroup), supporting loamy-clayey soils. Fc is the dominant land type, with Ae and Ag land types being of lesser importance.

Climate Willowmore Gwarrieveld has a pronouncedly aseasonal, bimodal (autumn-spring) rainfall pattern with slight optima in March and from October to November, with overall MAP 250 mm, which may vary considerably along an east-west gradient. MAT is in the warm-temperate range (16–17°C), but number of frost days here is higher than in the western regions of the Little Karoo. See also climate diagram for SKv 12 Willowmore Gwarrieveld (Figure 5.65).

Important Taxa Succulent Tree: *Aloe ferox*. Small Trees: *Pappea capensis* (d), *Acacia karroo*, *Schotia afra* var. *afra*. Succulent Shrubs: *Drosanthemum lique* (d), *Cotyledon orbiculata* var. *orbiculata*, *Crassula ovata*, *Drosanthemum delicatulum*, *Euphorbia mauritanica*, *E. rectirama*, *Exomis microphylla* var. *axyrioides*, *Lycium cinereum*, *L. oxycarpum*, *Pachypodium succulentum*, *Portulacaria afra*, *Tetragonia fruticosa*, *T. robusta* var. *psiloptera*, *Trichodiadema barbatum*, *Tylecodon paniculatus*. Tall Shrubs: *Euclea undulata* (d), *Cadaba aphylla*, *Diospyros austro-africana*, *D. lycioides*, *Grewia robusta*, *Gymnosporia*

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Figure 5.77 SKv 12 Willowmore Gwarrieveld: Park-like landscape near Kleinpoort (south of the Klein Winterhoekberge, Eastern Cape) with scattered individuals of *Pappea capensis* and dwarf succulent *Drosanthemum lique* in the undergrowth.

SKv 13 Prince Albert Succulent Karoo

VT 26 Karroid Broken Veld (77%) (Acocks 1953). LR 53 Great Nama Karoo (72%) (Low & Rebelo 1996). BHU 90 Prince Albert Broken Veld (81%) (Cowling & Heijnis 2001).

Distribution Western Cape Province: Broad flat-bottomed, colluvium-filled valleys between the north-facing slopes of the Swartberg and the parallel ridges that lie to the north of the Swartberg, this vegetation unit extends from around Gamkapoort Dam (west of Prince Albert) along the Swartberg foothills, as far as the Bosmanspoort area north of Willowmore. Altitude 480–1 120 m (most of area at 500–950 m).

Vegetation & Landscape Features Flat or only slightly undulating country with prominent parallel stony ridges in places, populated by low scrub where leaf-succulent vygies and small-leaved Karoo shrubs share dominance. Heuweltjies are an important feature of this vegetation—they occur at a density of about two per hectare, supporting succulent and salt-tolerant plant assemblages (*Augea, Brownanthus, Drosanthemum, Malephora, Psilocaulon, Ruschia, Salsola*).

Geology & Soils Sedimentary rocks of the Ecca Group (particularly the Fort Brown and Prince Albert Formations) together with diamictite of the Dwyka Group are most important in the area, and to a lesser extent shales and quartzites of the Devonian Witteberg Group. In places, Tertiary alluvial and slope deposits overlie these Karoo and Cape Supergroup rocks. This geology supports development of various cambisols and leptosols. Fc is the dominant land type, while Ag land type plays only a minor role.

Climate Due to the rainshadow of the Swartberg Mountains, the MAP reaches only 165 mm. The rainfall pattern is equinoctial, with highest incidence from March to April and later from

polyacantha, *Nymania capensis*, *Putterlickia pyracantha*, *Rhus longispina*, *R. lucida*, *R. undulata*. Low Shrubs: *Eriocephalus ericoides* (d), *Galenia africana* (d), *Pentzia incana* (d), *Aptosimum elongatum*, *Asparagus burchellii*, *A. striatus*, *Carissa haematocarpa*, *Chrysocoma ciliata*, *Felicia muricata*, *Garuleum latifolium*, *Hermannia gracilis*, *Jamesbrittenia microphylla*, *Leucas capensis*, *Limeum aethiopicum*, *L. africanum*, *Pentzia sphaerocephala*, *Polygala seminuda*, *Pteronia adenocarpa*, *P. glauca*, *P. incana*, *Rhigozum obovatum*, *Selago fruticosa*, *Tripteris sinuata*. Semiparasitic Shrub: *Thesium lineatum*. Woody Succulent Climber: *Sarcostemma viminale*. Woody Climber: *Asparagus racemosus*. Semiparasitic Epiphytic Shrub: *Viscum rotundifolium*. Herbs: *Cineraria platycarpa*, *Lappula capensis*, *Leidesia procumbens*, *Lepidium desertorum*. Geophytic Herbs: *Ornithoglossum viride*, *Oxalis pes-caprae*. Succulent Herb: *Tetragonia microptera*. Graminoids: *Aristida diffusa*, *Cynodon incompletus*, *Digitaria argyrograpta*, *Ehrharta calycina*, *Eragrostis obtusa*, *Karroochloa tenella*, *Pentaschistis airoides*, *Sporobolus fimbriatus*, *Tragus berteronianus*, *T. koelerioides*.

Endemic Taxon Low Shrub: *Helichrysum fourcadei*.

Conservation Least threatened. Target 16%. Only very small patches statutorily conserved in the Kammanassie Swartberg East Nature Reserve. Grazing can be a problem in places, but basically only very little of the area has been transformed. No obvious invasions of alien plants detected. Erosion is moderate (52%), high (28%) and very low (11%).

Remark Vlok & Euston-Brown (2002) pointed out that the apparent lack of endemic species (in particular of the genera *Glottiphyllum* and *Haworthia*, showing local endemism in neighbouring vegetation units) is most peculiar.

References Acocks (1988), Vlok & Euston-Brown (2002).

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Figure 5.78 SKv 13 Prince Albert Succulent Karoo: Heuweltjies dominated by *Ruschia spinosa* surrounded by shrubland with *Drosanthemum praecultum, Brownanthus ciliatus, Pteronia pallens* and *Augea capensis* on the Farm Tierberg near Prince Albert (Western Cape).

October to November. Winter rainfall is about 46% of the total precipitation. The overall MAT is slightly above 16°C, while at the Farm Tierberg (near Prince Albert) MAT is 17.5°C, temperatures ranging from below 0°C to 30°C. Incidence of frost of 26 days a year is quite high. See also climate diagram for SKv 13 Prince Albert Succulent Karoo (Figure 5.65).

Important Taxa ([R]Rocky ridges) Succulent Shrubs: *Augea capensis* (d), *Drosanthemum praecultum* (d), *Malephora lutea* (d), *Ruschia spinosa* (d), *Adromischus triflorus*, *Aridaria noctiflora* subsp. *straminea*, *Cotyledon orbiculata* var. *orbiculata*[R], *Crassula subaphylla*, *Drosanthemum lique*, *D. vespertinum*, *Euphorbia atrispina*[R], *E. braunsii*, *E. caterviflora*, *Faucaria bosscheana*, *Glottiphyllum peersii*, *Hereroa fimbriata*, *H. odorata*, *Hoodia pilifera* subsp. *annulata*, *Hypertelis salsoloides*, *Kleinia longiflora*[R], *Leipoldtia schultzei*, *Lycium cinereum*, *L. oxycarpum*, *L. schizocalyx*, *Pachypodium succulentum*, *Peersia macradenia*, *Pelargonium karooicum*, *Prenia tetragona*, *Rhombophyllum dolabriforme*[R], *Salsola aphylla*, *S. tuberculata*, *Sceletium rigidum*, *Tetragonia spicata*, *Tylecodon cacalioides*, *T. ventricosus*[R], *T. wallichii* subsp. *wallichii*, *Zygophyllum lichtensteinianum*. Tall Shrubs: *Cadaba aphylla*, *Gomphocarpus filiformis*. Low Shrubs: *Pteronia pallens* (d), *Aptosimum indivisum*, *Asparagus burchellii*, *A. recurvispinus*, *Ballota africana*, *Berkheya spinosa*, *Blepharis mitrata*, *Chrysocoma ciliata*, *Eriocephalus ericoides*, *E. spinescens*, *Felicia filifolia*, *F. muricata*, *Galenia pubescens*, *Garuleum bipinnatum*, *Helichrysum rosum*, *Limeum aethiopicum*, *Macledium relhanioides*, *Menodora juncea*, *Monechma spartioides*, *Pentzia incana*, *Plumbago tristis*, *Polygala leptophylla*, *Pteronia adenocarpa*, *P. empetrifolia*, *P. glomerata*, *P. viscosa*, *Rhigozum obovatum*, *Rosenia humilis*, *Senecio angustifolius*, *Sericocoma avolans*, *Sutera archeri*, *Tripteris sinuata*, *Zygophyllum microphyllum*. Semiparasitic Shrub: *Thesium lineatum*. Woody Succulent Climber: *Sarcostemma viminale*[R]. Woody Climber: *Asparagus retrofractus*. Herbaceous Climber: *Fockea comaru*. Semiparasitic Epiphytic Shrubs: *Moquiniella rubra*, *Septulina glauca*[R], *Viscum capense*[R], *V. rotundifolium*[R]. Herbs: *Amellus microglossus*, *Cuspidia cernua*, *Dicoma capensis*, *Galenia papulosa*, *Galium tomentosum*, *Gazania krebsiana* subsp. *arctotoides*, *G. lichtensteinii*, *Hermannia pulverata*, *Lasiopogon glomerulatus*, *Lepidium africanum*, *L. desertorum*, *Lessertia annularis*, *Leysera tenella*, *Lotononis pungens*, *Manulea chrysantha*, *Oncosiphon piluliferum*, *Pelargonium minimum*, *Trichogyne polycnemoides*, *Ursinia nana*, *Wahlenbergia androsacea*, *Zaluzianskya peduncularis*. Geophytic Herbs: *Drimia intricata*, *Tritonia florentiae*. Succulent Herbs: *Aloe variegata*, *Brownanthus vaginatus*, *Conophytum truncatum*[R], *Crassula deltoidea*[R], *C. muscosa*, *C. tecta*[R], *C. tomentosa*[R], *Haworthia semiviva*, *H. viscosa*, *Psilocaulon junceum*, *Quaqua marlothii*, *Senecio radicans*, *Tetragonia echinata*. Graminoids: *Aristida adscensionis*, *A. congesta*, *A. diffusa*, *Cenchrus ciliaris*, *Digitaria argyrograpta*, *Enneapogon cenchroides*, *E. desvauxii*, *E. scaber*, *Eragrostis obtusa*, *Fingerhuthia africana*, *Stipagrostis obtusa*.

Biogeographically Important Taxa ([GKB]Great Karoo basin endemic, [S]Southern distribution limit) Succulent Shrubs: *Chasmatophyllum stanleyi*[GKB], *Cylindrophyllum tugwelliae*[GKB], *H. latipetala* [GKB], *Pleiospilos nelii*[GKB], *Rhinephyllum luteum*[GKB], *Ruschia crassa*[GKB], *R. perfoliata*[GKB]. Low Shrub: *Pentzia pinnatisecta*[S]. Geophytic Herb: *Tritonia tugwelliae*[GKB].

Endemic Taxa Succulent Shrubs: *Antimima erosa*, *A. piscodora*, *Glottiphyllum neilii*, *Hereroa brevifolia*, *H. carinans*, *Malephora flavo-crocea*, *Ruschia bijliae*, *R. brevipes*, *R. callifera*, *R. heteropetala*. Geophytic Herb: *Xysmalobium fluviale*. Succulent Herbs: *Astroloba herrei*, *Bijlia dilatata*, *B. tugwelliae*.

Conservation Least threatened, although exposed to overgrazing in some parts. Target 16%. Almost 3% statutorily conserved in the Gamkapoort, Groot Swartberg, Swartberg East and Towerkop Nature Reserves. A small portion is also protected on private land Klein Swartberg, Sunnyside Game Farm, Tierberg Farm. Building of the Gamkapoort Dam irreversibly transformed some portions of the unit. No serious alien invasions have been recorded. Erosion is moderate (76%) or low (14%).

Remark Tierberg Research Station (near Prince Albert) houses one of the finest examples of this vegetation unit and one of the best researched locations of the Karoo (see Milton et al. 1992 for references).

References Milton (1990a, b, 1994, 1995), Esler (1993), Esler & Cowling (1995), Wiegand & Milton (1996), Settele et al. (1999), Cowling & Heijnis (2001).

SKv 14 Steytlerville Karoo

VT 31 Succulent Karoo (74%) (Acocks 1953). LR 54 Central Lower Nama Karoo (93%) (Low & Rebelo 1996). BHU 92 Steytlerville Broken Veld (90%) (Cowling & Heijnis 2001).

Distribution Eastern Cape Province: Valley bottoms delimited by the Grootrivierberge in the north and Baviaanskloof Mountains in the south, spanning Willowmore in the west and the surrounds of the confluence of the Groot and Haaspoort Rivers in the west. Altitude 480–950 m.

Vegetation & Landscape Features Flat lowland regions interrupted by a series of low hills are supporting low karoid shrubland vegetation dominated by succulent vygies (*Drosanthemum, Faucaria, Glottiphyllum, Ruschia*) and asphodeloids (*Haworthia*), and other succulent shrubs (*Euphorbia, Zygophyllum*). Local dominance of nonsucculent shrubs such as *Rhigozum, Pentzia* and *Eriocephalus* as well as local dominance of C_4 grasses of the genera *Aristida, Eragrostis* and *Stipagrostis* points to relationships with karoo shrublands typical of the summer-rainfall area.

Geology & Soils The area is dominated by Traka Subgroup shale and minor sandstone (of the Bokkeveld Group) together with lesser quartzite and shale of the Witteberg Group (Cape Supergroup), and supports (in places) deep loamy-sandy soils. Ag is the dominant land form, followed by Fc land form, both making up almost 100% of the area.

Climate Aseasonal, but clearly bimodal precipitation climate with a major peak in March and another marked precipitation increase between October and December. MAP is almost 220 mm, which can be ascribed to the macrolandscape position of the unit located in a rainshadow valley. MAT 17°C, with 22 frost days per year. See also climate diagram for SKv 14 Steytlerville Karoo (Figure 5.65).

Important Taxa Succulent Shrubs: *Galenia sarcophylla* (d), *Ruschia spinosa* (d), *Antimima maxwellii*, *Augea capensis*, *Delosperma multiflorum*, *Drosanthemum delicatulum*, *D. fourcadei*, *D. lique*, *Euphorbia braunsii*, *E. esculenta*, *E. ferox*, *E. inermis*, *E. mauritanica*, *E. rectirama*, *E. rhombifolia*, *Faucaria bosscheana*, *F. felina*, *Glotihyllum oligocarpum*, *Hypertelis salsoloides*, *Lycium cinereum*, *Malephora uitenhagensis*, *Mestoklema tuberosum*, *Othonna carnosa*, *Phyllobolus splendens*, *Ruschia indurata*, *Salsola tuberculata*, *Sarcocaulon patersonii*, *S. vanderietiae*, *Tetragonia fruticosa*, *T. robusta* var. *psiloptera*, *Trichodiadema barbatum*, *Zygophyllum flexuosum*, *Z. lichtensteinianum*. Tall Shrub: *Asparagus acocksii*. Low Shrubs: *Eriocephalus ericoides* (d), *Pentzia incana* (d), *Rhigozum obovatum* (d), *Aptosimum depressum*, *A. elongatum*, *A. indivisum*, *Asparagus glaucus*, *A. stipulaceus*, *A. striatus*, *Barleria rigida*, *B. spinulosa*, *Bassia*

salsoloides, *Blepharis capensis*, *B. mitrata*, *Chrysocoma ciliata*, *Euryops anthemoides*, *Felicia filifolia*, *F. muricata*, *F. ovata*, *Galenia secunda*, *Garuleum latifolium*, *Helichrysum dregeanum*, *Hermannia cuneifolia*, *Jamesbrittenia atropurpurea*, *Limeum aethiopicum*, *Monechma divaricatum*, *Osteospermum microphyllum*, *Pentzia pinnatisecta*, *Phymaspermum parvifolium*, *Plinthus karooicus*, *Polygala leptophylla*, *P. seminuda*, *Pteronia sordida*, *Rosenia humilis*, *Selago fruticosa*, *Senecio acutifolius*, *Sutera halimifolia*, *Zygophyllum microphyllum*. Herbs: *Aizoon canariense*, *Cuspidia cernua*, *Chamaesyce inaequilatera*, *Galenia papulosa*, *Hermannia coccocarpa*, *H. pulverata*, *Indigofera pungens*, *Lepidium africanum*, *L. desertorum*, *Lessertia pauciflora*, *Lotononis pungens*, *Pelargonium minimum*, *Tribulus terrestris*. Geophytic Herbs: *Moraea pallida*, *Oxalis depressa*. Succulent Herbs: *Aloe longistyla*, *Crassula muscosa*, *C. orbicularis*, *Mesembryanthemum guerichianum*, *Portulaca oleracea*, *Psilocaulon articulatum*, *Tetragonia echinata*, *T. microptera*. Graminoids: *Eragrostis obtusa* (d), *Aristida adscensionis*, *A. congesta*, *A. diffusa*, *Cynodon dactylon*, *C. incompletus*, *Digitaria argyrograpta*, *Enneapogon desvauxii*, *Eragrostis homomalla*, *E. lehmanniana*, *Panicum stapfianum*, *Sporobolus fimbriatus*, *S. ioclados*, *S. ludwigii*, *S. tenellus*, *Stipagrostis ciliata*, *S. obtusa*, *Tragus berteronianus*, *T. koelerioides*.

Endemic Taxa Succulent Shrubs: *Aloinopsis schooneesii*, *Euphorbia bruynsii*, *Glottiphyllum difforme*, *Pleiospilos compactus* subsp. *minor*, *Ruschia mariae*. Geophytic Herb: *Eriospermum appendiculatum*. Succulent Herbs: *Aloinopsis rosulata*, *Haworthia bruynsii*, *H. sordida*.

Conservation The unit does not feature as threatened. Target 16%. None of the area is conserved in statutory conservation areas, although small portions enjoy some protection within private reserves such as the Monteaux Game Ranch and Timbili Game Reserve. Only about 2% of the area has been transformed and it has not been suffering from invasion of alien plants yet. Most of the area is under moderate erosion pressure.

Remarks This is the easternmost Succulent Karoo unit—a kind of anomaly in terms of the prevailing summer rainfall dominant in the area. It is embedded within a complicated geology and climatic setup in the region where Succulent Karoo, Nama-Karoo, Fynbos and Albany Thicket Biomes meet. Steytlerville Karoo shows biogeographical links (through a number of regional endemics) with the Albany Centre of Endemism on one side, and with a group of Succulent Karoo units (including Prince Albert Succulent Karoo, Willowmore Gwarrieveld and Eastern Little Karoo) on the other.

References Acocks (1988), Milton et al. (1995).

L. Mucina

Figure 5.79 SKv 14 Steytlerville Karoo: Karoo shrublands with *Pentzia incana*, *Eriocephalus*, *Lycium* and several succulent *Euphorbia* species west of Steytlerville (Eastern Cape).

10. Credits

Most of the original introductory text (including sections 1 and 3 to 7) was written by K.J. Esler. Section 2.1 (climate) was provided by L. Mucina and edited by P.G. Desmet and M.C. Rutherford; section 2.2 (geology) was contributed by R.A. Ward; section 2.3 (soils) was written by F. Ellis and J.J.N. Lambrechts and edited by L. Mucina. Section 3 was extended by L. Mucina. The account on climate-change modelling (in section 5) was contributed by G.F. Midgley.

L. Mucina wrote the descriptions of the units SKk 7 and 8, SKt 2 and 3, SKv 2–8, 11 and 14. He also contributed to SKr 18 and 19 (with P.G. Desmet), SKn 2 (with P.G. Desmet and N. Jürgens), SKn 3 and 4, 6–9 and 11 (with A. le Roux), SKs 13 and SKv 1 (with C. Boucher), SKv 9 (with conceptual contribution by J.H.J. Vlok and D.I.W. Euston-Brown), SKv 12 (with J.H.J. Vlok, D.I.W. Euston-Brown and M.C. Rutherford) and to SKv 13 (with S.J. Milton). N. Jürgens contributed descriptions of the vegetation units SKr 1–17 and SKs 1–6. Various versions of these descriptions were subject to extensive editorial changes and conceptual editing (both of the text, of the concepts of the vegetation units, and to an extent also of the species lists) by L. Mucina and M.C. Rutherford. U. Schmiedel wrote descriptions of SKs 10, SKk 1–6, SKv 10 (with L. Mucina) and SKs 12 (with A. le Roux and C. Boucher). A. le Roux contributed descriptions of SKn 1 and 4 and SKs 8, 9 and 11 (all with L. Mucina). P.G. Desmet contributed to the descriptions of SKn 2 and 5, SKt 1 (all with L. Mucina) and to SKr 18 and 19 (as second author).

The original mapping concepts were provided by the following authors: Richtersveld by N. Jürgens (with contributions by P.G. Desmet for the SKr units of northern Bushmanland); Namaqualand Hardeveld, Namaqualand Sandveld and Knersvlakte by A. le Roux (Knersvlakte with the assistance of U. Schmiedel). An unpublished map of the upper Olifants and Doring River region by Boucher (2003) served as basis for the definition of several southern Knersvlakte units and the Succulent Karoo in the Klawer-Citrusdal region. The regions of rainshadow valley and trans-escarpment karoo were mapped by L. Mucina and M.C. Rutherford, with important contributions by J.H.J. Vlok and D.I.W. Euston-Brown's STEP map (Vlok & Euston-Brown 2002) to the definition of the concepts and extent of the Little Karoo units and the Steytlerville Karoo. M.C. Rutherford and L. Mucina shaped the conceptual issues (identity and precision of mapping) of most of the vegetation units composing the Succulent Karoo, in particular those of the Richtersveld, northern Bushmanland, the Tanqua-Roggeveld region and the Little Karoo.

The photographs were contributed by L. Mucina, N. Jürgens, J.C. Manning, E.J. van Jaarsveld, P.G. Desmet, K. Phillips,

L.W. Powrie and M. Pfosser. L.W. Powrie and M.C. Rutherford prepared all climate diagrams and data for the conservation sections of descriptions of all vegetation units. L.W. Powrie assisted with extraction of species lists from the SANBI databases (PRECIS, ACKDAT) as well as with preparation of mapping material for contributors at various stages of the Project. Selections of the lists of species of particular vegetation units from these databases were done by L. Mucina.

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Desert Biome 6

Norbert Jürgens

with contributions by

Philip G. Desmet, Michael C. Rutherford, Ladislav Mucina and Robert A. Ward

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Figure 6.1 Population of rare *Aloe pillansii* (Asphodelaceae) overlooking the rugged desert terrain from Cornellskop, Richtersveld.

K. Phillips

1. Introduction: Delimitation and Global Perspective

The desert of South Africa is a part of the hyperarid region fringing the western South Atlantic seaboard, southern Angola (Mossamedes Desert) and Namibia (Namib Desert). The great age of aridity (presumably dating back to Late Miocene), extraordinary high diversity of organisms (including many endemics), a wide spectrum of adaptations to arid environments and the inclusion of both winter- and summer-rainfall areas make these desert areas one of the most interesting hyperarid regions in the world.

Within South Africa, the desert areas stretch from the Atlantic coast near the mouth of the Orange River and penetrate inland following the course of the lower Orange River as far as the vicinity of Onseepkans and Pofadder in northern Bushmanland. In the eastern part, most of the desert area within South Africa lies within less than 20 km from the Orange River and only very few parts are further than 30 km away from the river. This is mirrored on most of the Namibian side of the river, revealing a relationship between the low elevation of the land surface next to the Orange River and the formation of hyperarid desert conditions. West of 17° longitude the Namibian part of the Namib Desert is no longer limited to the larger Orange River Valley—the desert extends northwards over the whole coastal plain (with some interspersed enclaves of Succulent Karoo in the southwest) throughout Namibia into the southwestern corner of Angola. It must be emphasised that this broad desert area is very varied, containing fundamental biotic and climatic differences within it but the different desert types need more research and analysis. The South African desert covers only 0.5% of the territory of the Republic of South Africa.

The desert of South Africa borders the Nama-Karoo Biome in its eastern parts (summer-rainfall region) and the Succulent Karoo Biome in its western parts (winter-rainfall region). Some of the poorly researched high mountain peaks mapped as desert may show both climatic and floristic affinity to either the Succulent Karoo or Nama-Karoo Biomes.

The unit is characterised by ecological extremes. Of all the biomes, the Desert has the lowest amounts of and the highest variability in rainfall, in places the highest ever measured temperatures in South Africa (47.8°C at a standard weather station at Goodhouse), and in other parts (western areas of the desert) the highest incidence of coastal fog.

In the scientific literature, the concepts of desert vary greatly, depending on the discipline, the regional background and the viewpoint of the individual researcher. These diverse approaches result in a 'desert' varying widely from, for example, areas 'where desert pavement and varnish are common phenomena' (Evenari 1985) to dry woodlands (Evenari et al. 1985). Therefore, many vegetation scientists rather avoid terms like 'desert' and prefer to describe the vegetation structurally or functionally, e.g. by the predominance of annual plants (Rutherford & Westfall 1994).

Annual plants are normally expected to dominate zonal areas of extreme deserts (Van Rooyen 1999). An attempt in southern Africa (Rutherford & Westfall 1994, Rutherford 1997) to define desert explicitly as dominated (averaged over many years) by annual plants becomes complicated by the need to exclude from the defined desert the washes and many other microazonal water-concentrating features such as the base of rock slabs with their relatively many perennial plants. Even when all areas in a desert region are included, a structural definition of 'desert' is not necessarily clear. Within the areas of South African desert, plant functional types have evolved and show very different and specific responses to aridity. In the eastern parts (Gariep Desert), grasses and woody shrubs are dominant, while in the western parts (Southern Namib Desert) leaf-succulent chamaephytes are most important. At this stage of research, no widely applicable vegetation-structural definition of 'desert vegetation' would be scientifically well founded.

In this publication, the concept of 'desert' is roughly defined by two parameters: (1) the climatic limit of less than approximately 70 mm or approximately 80 mm of MAP in the easternmost parts, and (2) by sparse perennial vegetation of less than 10% canopy cover. By this definition, most of the landscapes along the lower Orange River and the northernmost tip of the Namaqualand Coastal Plain near Alexander Bay are considered 'desert'. Some coastal regions with less than 70 mm of MAP are excluded from 'desert' where vegetation cover exceeds 10%, e.g. some areas of Succulent Karoo north of Port Nolloth, due to additional water supply by fog and to the greater effectiveness of the soft cyclonic rains of the winter-rainfall regions compared to that in areas further east with intense convective rains under hot conditions in summer (Rutherford 1997). Werger (1978a) indicated about 60 mm as the southern climatic limit of his Namib Domain, while Jürgens et al. (1997, p. 194) suggested 100 mm isohyet as an approximation to the boundary of 'desert biome'. This latter limit does not take into account the important role of seasonality of rainfall on the soil water balance. The diversity of opinions on the most plausible climatic limit of 'desert' reflects the continuum (or 'cascade' as understood by Jürgens et al. 1997, p. 195) character of transition between 'desert' and neighbouring semidesert biomes.

As already recognised by Jürgens et al. (1997, p. 194), the true desert regions of southern Africa show clear climatic and biogeographic, and we may also add obviously also evolutionary, dichotomy. The western desert regions are characterised by winter rainfall (albeit erratic) and typical incidence of fog, while the eastern desert regions are characterised by increased summer rainfall. The former shows floristic and evolutionary links to the Succulent Karoo Biome (and is considered as part of the Greater Cape Floristic Region or Kingdom; Jürgens et al. 1997), while the latter shows links to the Nama-Karoo Biome and the Palaeotropical Floristic Kingdom. At this stage we refrain from classifying these two distinct regions as biomes and suggest treating them as separate bioregions, such as the Southern Namib Desert Bioregion (part of Namib Desert) and the Eastern Gariep Desert Bioregion (part of Gariep Desert), respectively.

All deserts along the subtropical high pressure belt experience low summer rainfall at their tropical margin and low winter rainfall at their poleward margin (Sahara and Atacama Deserts). The summer-rainfall margins of all these deserts have many vegetation patterns in common, although tall-stem succulents are better represented in the Americas and less important in deserts elsewhere. Winter-rainfall deserts (including parts of the Namib and Atacama Deserts, the driest regions of the Canary Islands and southwestern Morocco), in contrast, show many unique features, among which the increased importance of low leaf-succulent shrubs is the most striking.

2. Climate, Geology and Soils

2.1 Climate

Several special features of the climate system are responsible for the aridity and for the different seasonality of the region. While the stability of the South Atlantic high-pressure Hadley Cell

defines the general aridity of the coastal area, during the summer months, cold fronts of the circum-Antarctic cyclonic belt and, to a lesser extent, coastal lows and the formation of West Coast troughs bring rain to the western parts of the Desert Biome. These sources of rain affect the eastern parts of the Desert Biome (Gariep Desert) to a much lesser degree. There, a hot low, developing in the hot Orange River basin, is responsible for late summer rains with a high inter-annual variability.

By definition, the area is one of extreme aridity with a MAP generally below 70 mm. All rivers in the biome are consequently nonperennial with the exception of the Orange River which receives its water from well outside the biome.

N. Jürgens

Figure 6.3 Malmokkie fog cloud as seen in the morning 4 km south of Brandkaros in the lower Orange River Valley.

Many climatic parameters show considerable spatial variation due to significant topographic variation, mountain barriers and, especially, distance from the sea. The higher-altitude mountains are cooler and have somewhat higher levels of precipitation than the lowland areas and deeply cut ravines. Barriers, such as the Stinkfonteinberge, to the advection of winter cyclonic rain from the west create rainshadows in many places to the east. The differences between the west of the biome (Southern Namib) and the eastern part (Gariep Desert) are clearly exemplified by the climate diagrams of Alexander Bay (Figure 6.2), representing the Southern Namib, and Goodhouse (Figure 6.2), representing the Gariep Desert. Alexander Bay shows a flat and relatively low temperature curve, without much variation over the months of the year, typical of an oceanic climate determined by the Atlantic Ocean and its low water temperature. The mean temperature is 17.2°C. In contrast, Goodhouse shows a continental curve, with a mild winter and a very hot summer, resulting in a mean annual temperature of 23.3°C. The difference in summer temperature maxima between the two stations is about 15°C. The Gariep Desert is the hottest area within the whole of southern Africa. Frost is not of any importance for the desert units close to the coast and at low altitudes further inland, while some frost occurs on higher mountain peaks, especially in the eastern units. MAP at both the above stations is close to 50 mm. However, while Alexander Bay has its rainfall peak clearly in the winter months, Goodhouse has a late summer rainfall peak. Rain at Alexander Bay is far more predictable (CV 43%) than at Goodhouse (CV >65%). This relates to the type of rainfall. At Alexander Bay cyclonic rain events tend to be generally distributed over most of the landscape, while at Goodhouse intense convective rains with thunderstorms often discharge over only a small area. This spatial heterogeneity can be equivalent to the temporal heterogeneity for single sites. In addition, the softer rain and drizzle of the cyclonic precipitation are much more effective for plant growth, when compared to the intense rainstorms which often generate runoff and formation of sheet washes. Also, the lower temperatures that prevail during the rain season greatly reduce evaporation compared to the high evaporation in the high temperature rain season in the east.

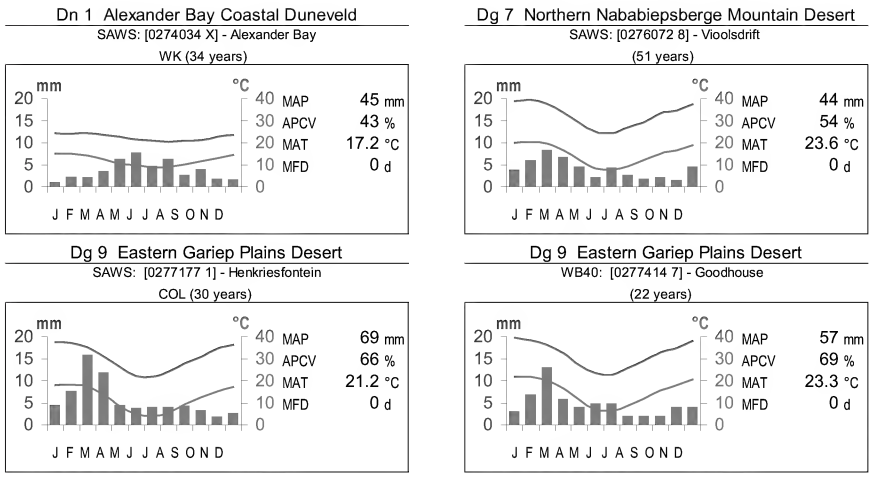

Figure 6.2 Climate diagrams of selected climate stations in Desert units. Blue bars show the mean monthly precipitation. The upper and lower red lines show the mean daily maximum and minimum temperature respectively. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days (days when screen temperature was below 0°C).

Advective fogs, resulting from the cooling of moist oceanic air as it passes over coastal waters chilled by the Benguela Upwelling System, are a distinctive feature of the Namib climate (Olivier 1992, 1995, Lancaster 2002). Its influence is felt as deep as 100 km inland. Fog is the most important additional source of water for plants in the coastal Namib Desert (Seely 1978) and enhances weathering and mineral breakdown (e.g. Goudie 1972, Eckhardt & Schemenauer 1998). In the Southern Namib, fog is frequent in the extreme west and on seaward hills and ridges on the coastal plain, where strongly wind-driven low cloud can also significantly precipitate water directly on to plants. A narrow band of fog is frequently observed moving inland along or building up above the Orange River Valley. Locally, this phenomenon is named

'malmokkie' (Figure 6.3). Upstream of the Sendelingsdrif/Lorelei area fog rapidly becomes of little importance and is absent further east.

In the coastal region, especially near Alexander Bay, high wind speeds, predominantly from the south, generate sandstorms with a very strong mechanical impact on plants, topsoils and rocks. Further inland, dust devils are frequently formed in summer.

2.2 Geology and Soils

The geology of the northwestern corner of South Africa and the southern part of Namibia is dominated by two important orogenic events that formed the Namaqua-Natal metamorphic belt (Mokolian Erathem) and the Gariep metamorphic belt (Namibian Erathem). The eastern edge of the Namaqua-Natal metamorphic belt is considered as the western boundary of the Kaapvaal Craton and also extends to become its southern boundary in KwaZulu-Natal.

The Namaqua metamorphic belt (hereby referring to the northwestern part of the larger belt only) formed under high-grade metamorphic conditions around 1 100 mya during a cycle of orogenesis that relates to several belts of similar age in central and eastern Africa. Sedimentary and volcanic rocks of around 1 600–1 300 my old, that were deposited on the edge of the Kaapvaal Craton as well as in the ocean basin to the west, were caught up in the metamorphism. These rocks were intruded by numerous granitoid plutons during the metamorphism and the intrusions continued for a period after the orogenesis had ceased.

The above is a slight simplification because two 1 900 my old fragments of continental crust are caught up in the Namaqua metamorphic belt. The Kheis Province actually separates the Kaapvaal Craton from rocks affected by the Namaqua deformation, and the Richtersveld Terrane of the lower Orange River area is a similar piece of continental crust but has been deformed in part during the Namaqua-Natal event. Both the volcano-sedimentary Orange River Group and the intrusive Vioolsdrif Suite of the Richtersveld support desert vegetation of large areas of the lower Orange River.

At the end of the Precambrian, the supercontinent Gondwana was assembled during the Pan-African orogenic cycle, resulting in the development of several orogenic belts. The Gariep metamorphic belt thus corresponds to a number of other belts in Namibia and South America as having formed in the same period of supercontinent assembly (these other belts include the Damara, Kaoko and the Dom Feliciano). The Saldanha belt of the Western Cape also correlates.

Rocks of the Gariep Belt were deposited on crust formed during the Namaqua-Natal orogeny in a rifting event that opened up an ocean basin to the west of the Namaqua-Natal Belt around 750 mya. During the later closing of this ocean to again form an orogenic belt (the Gariep) at 550 mya, some of this oceanic crust became caught up in the Gariep Supergroup to form a metamafic rock. The Gariep Supergroup contains a variety of sediments and, very interestingly, contains both carbonate deposits and diamictites (interpreted to be glaciogenic), which are believed to have formed within a short period of time of one another. This is surprising, because it suggests that carbonates, formed in a warm-water environment, are found in the same sedimentary basin as glacial deposits without sufficient time for continental drift to accommodate the expected change in latitude. Other evidence from around the world also points to a possible super-ice age(s) at this point of the earth's history (Hoffman 1999).

The orogenic event also resulted in the formation of a depositional basin into which the Nama Group sediments were deposited.

Since the Gariep orogeny, no mountain-building event has occurred in the region, but erosion has removed a thick portion of the crustal material to reveal the high-grade zones (i.e. deep crustal levels) of the metamorphic belts. This has resulted in the peneplanation of large areas of Namaqualand.

In more recent times the coastal areas have experienced several events of marine transgression, leaving a coastal strip covered in shallow-marine sands as well as aeolian deposits. This coastal strip covers the underlying geology in large areas adjacent to the coast.

The soils of the desert are very slow-forming and subject to being eroded by wind storms in the west and by high-impact rain from convective thunderstorms in the east. The deepest accumulations of alluvial (and some colluvial) material occurs in the washes and in the mobile aeolian sands nearer the coast. For the most part, the substrate is very rocky, with very little to no soil. Unobserved micro-accumulations of soil probably occur in narrow crevices and splits in rocks. Desert algal crusts, where they occur in the coastal fog belt, may assist in resisting erosion. Land types are predominantly Ic with some Fc and Ib. In the washes and flats there are Ag and Ae land types, and Ai and Ia land types are found on the coastal plain.

3. Biogeography: Origins, Diversity Patterns and Classifications

3.1 Palaeogeographic Patterns

Undoubtedly the origin of the coastal Namib Desert, and possibly also of the Gariep Desert found deeper inland, is linked to the origins and further development of the Benguela Upwelling System (Dupont et al. 2005), one of the greatest upwelling systems of the world. The Namib Desert stretches over 2 000 km from about the Orange River mouth at approximately 32° S to where the northern boundary of the permanent upwelling zone and the northern boundary of the Benguela Current (Angola-Benguela Front) coincide with the northern boundary of the Namib Desert at about 15° S (Shi et al. 2000). The origin of the upwelling system dates back to presumably as early as the Late Miocene (Siesser 1980)—it is supposed to have established at around 14 mya as a direct consequence of the establishment of the Antarctic Ice Shield. The upwelling system is closely linked to trade-winds; fluctuation in the intensity of the trade-wind systems reflects deeply in the fluctuations of the intensity of the coastal upwelling (Shi et al. 2000, Udeze & Oboh-Ikuenobe 2005).

The formation of the Namib Sand Sea by aeolian transport of sands originating from river sediments of the lower Orange River System dates back to the Middle Miocene. Already at that time a Namib Dunefield developed, which is well conserved in the form of the Tsondab Sandstone Formation on the Farm Dieprivier. These fossil dunes are rich in fossils. The occurrence of nest sites of modern termites like species of *Psammotermes* and *Hodotermes* and even of webs of *Soethyra* spiders indicates that a large proportion of modern Namib Desert organisms had already evolved under very similar ecological conditions in the Middle Miocene (Pickford 2000, Pickford & Senut 2000, 2002).

The fossil record of raised beach levels along the Namib coast, caused by strong sea level fluctuations during the Cenozoic, indi-

cates that the full establishment of the cold Benguela Current only occurred in the Early Pleistocene (Pickford & Senut 2000).

Archaeological data indicate that in the Holocene the Namib region (and especially the Southern Namib along the lower Orange River) did not experience a humid phase, but was more or less at the current level of aridity (Vogelsang 1998).

3.2 Origins of the Desert Flora and Vegetation

The formation of this desert flora is directly linked to the formation of the desert climates and associated physiogeographic peculiarities of the complex hyperarid region currently fringing the seaboard (as well as adjacent inland regions) of the Atlantic coasts of northern South Africa, Namibia and southernmost Angola. The age of the Namib Desert is a subject of considerable scientific debate. Following the most recent compilations of geological and fossil evidence (Van Zinderen Bakker 1975, Ward et al. 1983, Schneider 2004, Schneider & Marais 2005), full desert conditions have prevailed since the Middle Miocene (ca. 15 mya), although a phase of more humid climatic conditions appeared towards the Late Miocene.

There is little information on the evolution of the taxa that form the vegetation of the southern African coastal desert today. Current phytogeographic patterns (e.g. sharing number of species and genera) show links of the southern Namib Desert with Succulent Karoo on one hand, and Eastern Gariep Desert with Nama-Karoo (*sensu* Jürgens 1991) on the other.

The desert belt along the coast and the desert belt along the Orange River obviously have formed the routes for major migrations during the Pleistocene, as can be derived from various findings, including pollen analysis (Scott 1995), analysis of deep marine sediments (Shi et al. 1998, 2000), the relict character of inselberg floras (Burke et al. 1998) and disjunct distribution areas (Jürgens 1991, 1997).

It is remarkable that a pollen record from a locality in the Richtersveld, found only 2 km outside the borders of the desert, suggests that karoo-shrub vegetation which included the *Elytropappus/Stoebe* element, occupied the area during the terminal Pleistocene phase (Scott 1995). Disjunct distribution patterns link the Eastern Gariep Desert with the Northern and Central Namib as well as with the Eastern Cape. They are also interpreted as a result of the last glaciation, which led to fragmentation of formerly much larger distribution areas of species of the Nama-Karoo Region (Jürgens 1997).

3.3 Diversity and Taxonomic Patterns

Plant species richness of the desert units is very high when compared with other deserts at the same level of aridity globally. Especially in the Richtersveld, diversity is remarkably high and does not differ much from that in the Succulent Karoo part of the Richtersveld. The diversity may be viewed as moderate in some of the plains vegetation units along the lowest Orange River Valley, especially in the Western Gariep Lowland Desert vegetation unit. It is very high in the mountainous desert sections of the Richtersveld (including Noms Mountain Desert, Richtersberg Mountain Desert, Kwaggarug Mountain Desert and Kahams Mountain Desert) and lower in the region around Henkries and Goodhouse (Eastern Gariep Rocky Desert).

In all units west of the Noms Mountain Desert, the families Aizoaceae, Crassulaceae, Zygophyllaceae, Fabaceae and Asteraceae appear as the most diverse. In the eastern units, the families Acanthaceae, Poaceae, Capparaceae and Amaranthaceae are more important.

The high diversity of the flora in the southern African deserts is related to the high age of the deserts and existence of two distinct centres of endemism, such as the Western Gariep CE and East Gariep CE, which might have served as refuge areas during the last glaciation.

3.4 Biogeographical and Vegetation Subdivisions

Many previous works have included the region of South African deserts in a much larger arid zone unit, for example the Karoo-Namib phytogeographical (White 1971) or phytochorological (Werger 1978b) (Floristic) Region, which was understood as a part of the Palaeotropical Floristic Kingdom, without recognising the difference between Succulent Karoo and Nama-Karoo. More recently, a fundamental distinction has been drawn between the western and eastern sections of the Karoo in terms of biome classification (Rutherford & Westfall 1986, Rutherford 1997), floristic composition (Bayer 1984, Gibbs Russell 1987) and biogeography (Jürgens 1991, 1997). Thus recognised was an arid part of the Succulent Karoo (biome or phytochorion) with its Fynbos or Capensis affinities in the west, and the arid part of the Nama-Karoo (biome or phytochorion) with its affinities to the Sudano-Zambezian flora in the east (Jürgens 1997).

Even more recent is the recognition of several types of deserts within the borders of South Africa. Most authors recognised that the concept of desert in South Africa was linked to the Namib Desert, located between the coast and the Escarpment. Its southern limit was established just south of Alexander Bay (Werger 1978a) or north of Lüderitz (Rutherford & Westfall 1994). The latter authors viewed the stretch south of Lüderitz as a hyperarid but fog-fed form of the Succulent Karoo Biome. Jürgens (1991) implicitly widened the concept of the desert by (a) including a wide arid belt around the lower Orange River and spanning the Richtersveld in the west and the surrounds of the Pofadder region in the east, and (b) recognising three subunits (districts), such as Eastern Gariep, Western Gariep and Southern Namib (see Figure 4 in Jürgens 1991).

The Southern Namib Desert Bioregion comprises the desert areas along the lowest part of the Orange River between Alexander Bay and Sendelingsdrif and shows the characteristic climatic properties of the southern parts of the coastal Namib Desert, such as a rainfall peak in winter (caused by cyclonic rains), mild temperatures due to the cooling Benguela Current, and a high frequency of fog. The Southern Namib Bioregion corresponds closely to the combination of the South African part of the Southern Namib District (Jürgens 1991) and the West Gariep District (Jürgens 1991). Jürgens (1991) separates the latter biogeographical district as a distinct centre of endemism. In this chapter, the nomenclature of the component vegetation units of the Western Gariep Centre, namely of the Dn 3 Western Gariep Plains Desert, Dn 4 Western Gariep Lowland Desert and Dn 5 Western Gariep Hills Desert, reflects this grouping. A much larger surface area in Namibia forms part of the Southern Namib Desert (Jürgens et al. 1997).

The Gariep Desert Bioregion includes the desert areas from Sendelingsdrif to the vicinity of Onseepkans/Pofadder and shows the characteristic climatic properties of the continental part of the Namib Desert. Fog is unimportant and absent as one proceeds eastwards within the Gariep Desert Bioregion. This is the hottest area within the whole of southern Africa. Rainfall is mainly caused by convective thunderstorms in summer, with

very low predictability and high temporal and spatial variability. Air humidity is much lower than in the Southern Namib Desert Bioregion. The Gariep Desert Bioregion corresponds to a limited subset, yet core area, of the East Gariep District (Jürgens 1991), later called the East Gariep Centre (Jürgens 1997, Jürgens et al. 1997). The East Gariep Centre includes a much wider area than the bioregion, taking in a much larger part of the surrounding Nama-Karoo Biome or considered within the Nama-Karoo Region (*sensu* Jürgens 1991), especially in Namibia (Jürgens 1991, 1997). Rutherford (1997) adopted the concept of desert occurring inland of the coastal belt, but viewed much of the desert corridor extending up the Orange River Valley as less than 20 km across (the explicit scale limit set for a biome) and hence limited the inland part to the area where it is at its widest, mainly in Namibia north of Noordoewer (on Orange River).

In the interface zone between the two bioregions, at a more detailed scale, many mountains and valleys have vegetation of the Southern Namib Desert (and Succulent Karoo) on south-western slopes and that of the Eastern Gariep Desert (and Nama-Karoo) on northeastern slopes.

While the large number of endemic species along the Orange River have often been seen as a single centre of endemism (e.g. Gariep CE of Van Wyk & Smith 2001), a more detailed appraisal confirms that there are two very different centres of endemism, albeit located close to each other (Jürgens 1991, 1997). While these two centres of endemism are climatically well separated, it has been proposed that they formed refugia for survival during the last glaciation for most of the endemic taxa (Jürgens 1991, 1997, Midgley et al. 2001). Conservation of taxa may have been mainly supported by gorge systems within dissected mountain areas, inselbergs, and dunes in the coastal Sandveld.

The substantial number and kinds of differences between the southern Namib Desert and Gariep Desert Bioregions (see above) could well be considered adequate grounds for these two units being recognised as two different biomes. However, due to the need for availability and analysis of floristic data and climatic conditions in other hyperarid regions particularly to the north of our mapped desert units, conclusive arguments cannot be put forward at this stage. See further discussion in the chapter on Biomes and Bioregions.

4. Ecology and Plant Adaptations

Almost all research on functional ecology and ecophysiology of plant species that occur in the South African desert has been carried out in the adjacent Succulent Karoo Biome (Rutherford 1991, Von Willert et al. 1992, with the exception of Rundel et al. 1995). The research findings are probably to some degree also applicable to the same species in desert, especially where a research site in the Succulent Karoo was located close to the edge of the desert (see the chapter on Succulent Karoo in this book).

Adaptations to the desert conditions are very different within the two bioregions. Within the Southern Namib Desert Bioregion leaf-succulent woody chamaephytes and low or thin stem succulents probably form the most obvious adaptation (Jürgens 1986) to relatively predictable rains falling during the cooler time of the year, as is also characteristic for the Succulent Karoo (see the chapter on Succulent Karoo in this book). In addition, a high number of species show peculiar growth forms, which are sunken into the soil surface. Only certain parts of leaves and/or stems appear above ground for at least a larger part of the year, allowing for photosynthesis, flowering and fruiting. In some cases, e.g. *Fenestraria rhopalophylla*, translucent windows allow entry of light into the inner parts of leaves, which are embedded into the soil, thereby allowing for photosynthesis below ground level.

Another special adaptation to desert conditions is the formation of sticky surfaces, which fix mineral sand grains to plant surfaces. These so-called 'psammophorous plants' (i.e. sand-carrying plants) are understood as an adaptation shielding the plants against the mechanical impact caused by the very frequent and strong sand storms of the coastal desert environments (Jürgens 1996).

Most leaf-succulent plant species of the West Gariep Centre are relatively short-lived, as is found in the Succulent Karoo regions of the Richtersveld (Jürgens et al. 1999, Gotzmann 2002). For these species, a well-adapted seed production, as well as dispersal, germination and establishment are critically important.

Within the Gariep Desert Bioregion with its extreme unpredictability of rainfall, other adaptations are of importance. Grasses are well adapted to survive long periods of drought without activity due to their sheath morphology which shelters their shoot apex and allows rapid growth in response to rains during the hot summer months. Woody shrubs within this unit do not bear succulent leaves, but rely on available groundwater ('phreatophytes'). Thus, woody shrubs and trees are restricted to topographical sites that store groundwater for a long period of time. These are mainly dry river beds, tilted plains above bedrock and mountain areas with fissured rock types.

Water storage within plants appears to require much larger volumes of water than in the Southern Namib Bioregion with its more predictable rainfall and shorter drought periods. Therefore, large stem succulents without leaves and with a green stem cortex like *Euphorbia gregaria* and *E. virosa* also form an important part of the vegetation at sites without persistent groundwater. Even longer periods of drought can be survived by plants remaining dormant, especially in those stem-succulent plants that possess a bark and form leaves only during the rainy season in summer (species of *Commiphora*), or in winter (*Pachypodium namaquanum*, *Tylecodon paniculatum*). The special adaptation of the northern orientation of the winter-leaved terminal part of the trunk of *Pachypodium namaquanum* is probably not a water-conserving measure but a way of almost doubling the midwinter radiation absorbance that it would have had with horizontal orientation (Rundel et al. 1995).

There are several strategies for plant survival common to both parts of the desert. Apart from the preponderance of survival through seed in annuals and the sometimes very short-lived ephemerals as well as facultative perennials, severe droughts can be survived by many of the plants by a stepwise death of parts (e.g. shedding of leaves, twigs, branches or stems) and regeneration of these organs after rain. Some species of *Salsola*, *Pteronia* etc. also fragment themselves actively into radial portions of the stem and root system ('stem splitting'; for definition see Schenk 1999), allowing survival of those radial portions of the plant with roots that have access to water. There are also a remarkable number of succulent annuals in the Southern Namib Desert. Underground storage organs like bulbs and tubers allow survival in both bioregions. Optimising short-term productive growth of the individual plant seems to be relatively unimportant in these areas. Several species are very flexible in their physiological response to availability of water. For example, the drought-deciduous *Ceraria fruticulosa* shows a highly flexible CAM expression (CAM-cycling, full-CAM and CAM-idling) in response to changes in availability of water (Veste et al. 2001).

Thorniness or spinescence is a common feature of some of the vegetation, with a study revealing the Namib Desert to contain 'highly spinescent noda' (Milton 1991).

Wind is one of the most important dispersal mechanisms (anemochory) in the arid western areas of South Africa (Van Rheede van Oudtshoorn & Van Rooyen 1999). In the desert, examples include *Pharnaceum croceum* and *Hypertelis salsoloides* with dust-like (very light) seeds, *Dicoma capensis* and *Pelargonium crithmifolium* with plumed seeds, and *Tripteris amplectens* and *Foveolina dichotoma* with winged seeds. Even within the same dispersal type, efficacy of movement can vary much. For example, under experimental conditions, seeds of *Pelargonium crithmifolium* need less than half the wind speed to start moving than that needed for *Dicoma capensis* (2.9 versus 7.2 km/hr, respectively; Van Rheede van Oudtshoorn & Van Rooyen 1999). Some species are adapted for both promoting and restricting movement. For example, the seed of *Heliophila thunbergii* var. *macrostylis* has a broad wing but produces copious amounts of mucilage from the epidermis of the testa when wet which acts as an anchoring mechanism (myxospermy), also after dispersal. There are a range of other mechanisms by which many desert plants hinder the long-distance dispersal of their seed (antitelechory). In deserts, space already occupied is usually the most suitable for growth. Also, many species are annuals and the space occupied by the mother plant becomes available the following season (Van Rheede van Oudtshoorn & Van Rooyen 1999).

With regard to the composition and structure of communities, the respective parts of the desert units can be seen as a filtered subset of Nama-Karoo (not dominated by leaf-succulent shrubs) or of Succulent Karoo (dominated by leaf-succulent shrubs). Another feature, especially in the eastern portion of the desert, is that plant communities are reduced to very few member taxa or even form monotypic populations in some habitats.

It is possible that some of the findings from the nearby Numees site in the Succulent Karoo Biome may apply to some extent in the Southern Namib Desert Bioregion. This may include the remarkably high turnover of some leaf-succulent Mesembryanthemaceae shrubs (Jürgens et al. 1999, Gotzmann 2002). However, climate-driven dynamics are likely to develop in longer cycles in desert.

Such a cycle of at least 18 years could be described at Numees in the Richtersveld (MAP 78 mm, mainly winter-rainfall). Subsequent to two drought years (1978 and 1979), annual observation of permanent plots allowed the documentation of the slow regeneration of populations and community during the subsequent 18 years (Jürgens et al. 1999, Gotzmann 2002).

In the areas with very highly variable summer rainfall in the eastern part of the desert units (Gariep Desert Bioregion), population dynamics are very slow. Succulents store large amounts of water (*Euphorbia virosa*, *Commiphora* species, *Pachypodium namaquanum*) in order to buffer very long periods of drought.

5. Status

Desert environments are not very attractive for humans, especially human habitation. Nevertheless, even a low level of human activity can have a high impact due to the sensitivity of desert environments. Archaeological information shows that during most of the Holocene only a very limited human population based their life as hunter-gatherers on the arid fauna and flora (Vogelsang 1998). There is no evidence that the arrival of stock, approximately 1 300 years ago (Webley 1997) led to any significant changes to the vegetation. Grazing pressure remained at a low level for another 1 800 years until white farmers and hunters (biltong production) impacted negatively on the natural ecosystems. By the second half of the 20th century the populations of game like zebra, oryx, kudu, ostrich and springbok were nearly exterminated. The influence of the resulting changes in the grazing regimes on vegetation remains unclear. The diet selection of goats in the communally grazed Richtersveld National Park has been studied in detail by Hendricks et al. (2002).

Forced removals from other regions and settlement programmes contributed to the increase in desert land use, e.g. in the southern Richtersveld. While communal land tenure was the traditional form, the state supported the subdivision and fencing of economic units in parts of the desert biome, e.g. in the southern Richtersveld. A number of private farms were also established along the lower Orange River.

Communal farming has remained in place in the northern Richtersveld communal area (which does not apply in southwestern Namibian desert areas that are also largely conserved in statutory reserves), whereas in the past a traditional seminomadic system was developed in adaptation to the seasonal changes in the different grazing resources. These include the coastal plains (Sandveld), the mountains, the desert plains (especially after good summer rains) and the perennial Orange River with its gallery forest and drinking water. The unique combination of a perennial river near the boundary between winter-rainfall and summer-rainfall climate resulted in a lower impact on the environment and vegetation than in the farming units further south (Jürgens 2001). However, strong degradation took place at stockpost sites (Hendricks et al. 2005), around the permanent settlements like Kuboes, Eksteenfontein and Lekkersing, and in those habitats that were particularly attractive for pastoral use in the close vicinity to the permanent settlements. Early photographic documents from 1914 show that since that time the Annisvlakte plain (Dn 4 Western Gariep Lowland Desert) lost its original vegetation cover. What had been a community with *Brownanthus pseudoschlichtianus* has been replaced by *Euphorbia gummifera* and *Mesembryanthemum hypertrophicum*. In the same time span, the fertile loamy-sandy soil which is always correlated with the *Brownanthus pseudoschlichtianus* community, was lost and replaced by a coarser saline soil. Also the adjacent populations of the tall succulent tree *Aloe pillansii* show a strong decrease in number of adult individuals. A detailed study by Bolus et al. (2004) analyses the complex population structures and interprets the decrease as a signal of climate change. A similar decline in *Brownanthus pseudoschlichtianus* over the past 60 years can be observed in the Koeroegabvlakte. The highest density of stockposts within the Richtersveld National Park is observed in the Koeroegab (H. Hendricks, pers. comm.). Along the slopes of the Goariep Mountain, young gully erosion underlines the decline of vegetation of mountain ecosystems.

Repeat photography also shows signs of severe desertification in the coastal plains near Alexander Bay. However, these changes as well as those on the Annisvlakte plain could well be a consequence of climate change. Recent analysis of the population dynamics of *Aloe dichotoma* (Foden 2002) is interpreted as a result of climatic change, which is mainly expressed by a decline in precipitation over the past decades.

Alien biological invasions in the desert appear to have had limited impact thus far. *Prosopis* is present at a number of settlements and along the Orange River, but it is not spreading further outside the river alluvium. *Nicotiana glauca* has become an

element of nearly all dry river beds, and along the Orange River *Ricinus communis* is also being found more frequently. Other alien problem plants of the arid zone further south, like *Atriplex lindleyi*, appear to have stopped their migration northwards in the southern Richtersveld.

Already in the 18th century, mining and prospecting added to the other human impacts on the ecosystem. Open-cast diamond mining has created big, although local, wounds in the landscapes along the Orange River from Alexander Bay to the Rosyntjieberge. An additional impact is caused by the deposition of the overburden within the wider landscape. For example, in the lower Annisvlakte near Swartwater, a huge deposition of soil material has taken place over a number of years, which has already destroyed a large proportion of local endemic species such as *Euphorbia melanohydrata* (named after Swartwater).

Hyperarid regions are very sensitive to disturbance and degradation. Regeneration takes very long, especially if the soil and the seed bank are also degraded. Therefore, a hyperarid region with high biodiversity deserves a high protection status.

At present, less than 20% of the surface area of all the desert units enjoys a statutory form of protection. The largest conservation area is formed by the Richtersveld National Park, followed by the Nababiep Nature Reserve, established at and west of the Modderdrif Helskloof. Recently the formation of the Richtersveld Community Conservancy added some form of protection status to a wider area in the southern Richtersveld. In addition, two very small areas have been proclaimed National Heritage Sites: the lichen field near Alexander Bay and the Cornellskop with the famous population of *Aloe pillansii*. The rest of the Desert Biome does not enjoy any conservation status. However, a large proportion of the species and communities of the Desert also occur in Namibia north of the Orange River. Here, the Namibian part of the Richtersveld-Ai-Ais Transfrontier Park and the Sperrgebiet National Park constitute large-scale protection areas. The wider public perceive the region to be of high conservation value because it forms a centre of endemism as well as a hotspot of diversity.

6. Threats

Currently, seminomadic pastoral land use is still in place within the Richtersveld National Park and is entrenched within the contractual agreement between the South African National Parks and the northern Richtersveld community. It is very difficult to provide scientific evidence for the quality and quantity of the long-term impact of this dominant land use form, also outside the park. Furthermore, modern life styles, especially the use of motorised vehicles are slowly changing the patterns of land use. The use of these vehicles results in a concentration of stockposts along the roads, for example.

Until recently, the population growth has remained so low that settlements have not become a major driver for habitat conversion. However, the increase of roads and tracks is likely to exacerbate the dramatic erosion, especially in the more loamy soil types of the *Brownanthus pseudoschlichtianus* community. With the access by roads, illegal collecting of plants was made possible during the second half of the 20th century. The number of plants of mature *Pachypodium namaquanum* and *Aloe dichotoma* for example, planted in private gardens, around town halls and mine headquarters, make it obvious that large quantities of plants have been removed from their populations. An estimation of losses of smaller succulents is nearly impossible. Tourism is steadily growing and potentially adds to the problems associated with access by roads. Unfortunately, in 2004 new tourist accommodation facilities were constructed within the very sensitive arid semidesert ecosystems of the Richtersveld National Park, away from the Orange River.

Irrigation agriculture is another form of land use, currently expanding along the Orange River. While in the early 20th century irrigation agriculture was developed at the lower Orange River at Grootderm and Arrisdrif, these activities are now expanding into formerly untouched vegetation for ostrich and cattle farming. Further upstream, larger areas are used for cereals, grapes, melons, etc. The extraction of water from the river and the pollution by agrochemicals could well become a major problem for the ecosystems along the river. Furthermore, the belt of irrigation agriculture is interrupting the interactions between the river and the ecosystems further away.

Continuing mining at existing mines poses an ongoing threat to desert ecosystems and species, for example at Swartwater. In the last few years, small-scale mining has also been started in several places, exploiting formerly untouched smaller gravel deposits along the Orange River, e.g. at Grootderm and at Grasdrif. Further upstream, occurrence of minerals other than diamonds also causes scattered mining activities with local impact.

Another threat is global climatic change (Hulme 1996, Hulme et al. 1996), which is very difficult to assess or to predict (compare the discussion in the respective chapters for Nama-Karoo and for Succulent Karoo). However, a southward shift of the Namib Desert may already have taken place over the past decades, as the comparison of old photographs and analyses of aerial photography would show (N. Jürgens, unpublished data). An initial assessment of the possible susceptibility of the plant species of the Richtersveld National Park to climate change indicated that a significant proportion of the flora may be at risk with future climate change (Rutherford et al. 1999a). An independent broad-scale assessment of the effects of climate change on a few species currently found in the Desert Biome (Rutherford et al. 1999b) indicates that these species may all find the future climate unsuitable. Microhabitats may, however, still enable survival of many species in the area.

7. Actions

Irrespective of the question whether incentives towards sustainable management are generated by market mechanisms or by the tax system, it would be advisable to minimise the impact of the threats mentioned in the previous section. This would include: a reduction of stock, especially on the sensitive soil types; shifting tourism infrastructure from sensitive arid ecosystems to already disturbed settlements or to the Orange River; and using the overburden in diamond mines to refill existing holes and trenches. Especially the coastal devastation by mining should be subject to an ecological restoration programme along the lines proposed for the similarly degraded coastal belt north of the mouth of the Orange River (Burke 2001). From a botanical point of view, game should be reintroduced to previous levels. The flora probably evolved under strong grazing pressure in adaptation to and in co-evolution with herbivores, as the widespread toxicity and thorniness (Milton 1991) of the plants indicate. The eradication of wild game and their replacement with sheep and goats could have had a negative impact on plant diversity.

Small stock farming, conservation, mining, irrigation agriculture and tourism can co-exist in the wide spaces of the desert units, even to mutual benefit. However, this requires a discussion process and integrated planning.

8. Further Research

It is obvious that the desert unit as mapped in this publication has received virtually no ecological research interest. Research has been concentrated on the more productive ecosystems of the country, including the Succulent Karoo part of the Richtersveld which has received relatively much research attention. Even countrywide activities such as the Acocks's (1953) vegetation mapping did not consider the desert, due to the low farming potential and inaccessibility.

Research in all fields of study and at all scales is therefore needed. Assessment of the distribution areas of species and communities is still not sufficient, especially with regard to the mountainous regions. Monitoring of changes in vegetation and ecosystems has been established for the Succulent Karoo parts of the Richtersveld, but should be extended to the desert units. Such monitoring work should include research on population dynamics, based on individual plants. Phenology and triggering of phenological phases by environmental factors has not been covered at all. The role of seed banks is probably of very high importance at the edge of the Namib Desert, but data are lacking. The role and response of plant functional types and their very peculiar traits (e.g. psammophory) should be studied in more depth, as well as the response of plants to the predicted climatic changes, taking the possible role of local refugia into account.

With regard to the various forms of degradation and destruction, rehabilitation work and experimental research on the appropriate tools and methods, is necessary.

The fate of the Orange River with regard to water quality and the quantity of water flow with increasing water consumption for irrigation agriculture, is another crucial topic affecting the future development of the desert units, and requires research for management purposes.

Integrated management is needed for this sensitive region. It is therefore hoped that the present construction of the first phase of the Gariep Ecology Research Station will create suitable infrastructure to not only attract more researchers to this remote region, but also establish web-based information arising from all the data generated there.

9. Descriptions of Vegetation Units

Southern Namib Desert

Dn 1 Alexander Bay Coastal Duneveld

VT 34 Strandveld of West Coast (100%) (Acocks 1953). LR 55 Strandveld Succulent Karoo (81%) (Low & Rebelo 1996).

Distribution Sandy coastal forelands between the mouth of the Orange and Cape Voltas south of Alexander Bay. The unit borders on the Richtersveld Coastal Duneveld of the Succulent Karoo Biome to the south. Altitude 0–60 m.

Vegetation & Landscape Features Mainly flats with few hills, supporting a plethora of habitats differing especially in substrate characteristics (e.g. sand sheets, exposed crusts, gravel or rocks). Vegetation is sparse, composed of low shrublands dominated by deciduous, woody shrubs and leaf-succulent shrubs on gently undulating sandy substrates. Primary determinants of vegetation patterns are depth of sand over dorbank, calcrete or bedrock, and mobility of sand.

Geology & Soils White to beige, semimobile aeolian sands (Quaternary) over dorbank, gypsum deposits or metavolcanic bedrock (schist, chlorite, subordinate amphibolite) of the Grootderm Formation (Gariep Supergroup, Namibian Erathem).

Climate Winter rainfall with MAP 45–50 mm, but rainfall highly variable between years. At Alexander Bay WO (Figure 6.2) rainfall has been recorded from 17 mm in the driest year to 90 mm in the wettest. Mean monthly maximum and minimum temperatures at this weather station are 35.7°C and 4.4°C for April and July, respectively. Temperature is moderated by the cold Atlantic Ocean, except on infrequent occasions when easterly winds occur and temperatures can exceed 40°C. Frost not recorded. Annual daily cloud cover averages about 50% at 08:00 and about 25% at 14:00. Heavy dew and fog occur frequently. Very strong southerly winds dominate throughout the year and are the primary determinant of the distribution of sand substrate types.

Important Taxa Leaf-succulent Shrubs: *Amphibolia rupis-arcuatae* (d), *Galenia fruticosa* (d), *Salsola zeyheri* (d), *Stoeberia beetzii* (d), *Tetragonia fruticosa* (d), *Crassula atropurpurea* var. *cultriformis*, *Drosanthemum ramosissimum*, *Hypertelis angrae-pequenae*, *Jordaaniella cuprea*, *Lycium decumbens*, *Othonna sedifolia*, *Pteronia glabrata*, *Stoeberia utilis*, *Zygophyllum clavatum*, *Z. morgsana*. Leaf- & Stem-succulent Shrubs: *Brownanthus marlothii*, *Psilocaulon dinteri*. Stem-succulent Shrub: *Euphorbia burmannii*. Other Shrubs: *Lebeckia sericea*, *Tripteris oppositifolium*. Perennial Herb: *Crotalaria meyeriana*. Graminoid: *Cladoraphis cyperoides*.

Conservation Target 28%. None conserved in statutory conservation areas. Open-cast diamond mining has destroyed most of this vegetation type.

Remarks Floristically this unit is similar to the SKs 1 Richtersveld Coastal Duneveld to the south. It is separated from this unit by the shorter, sparser vegetation and stronger sand movement. According to Werger (1978a, b) this unit is the southernmost coastal unit to fall altogether within the southern extension of the Namib Desert. If sand is transported across this unit, it moves as a continuous thin sheet across the landscape and there are no mobile dunes.

References Acocks (1988), Desmet (1996), Low & Rebelo (1996, 1998), Desmet & Cowling (1999), Jürgens (2004).

Dn 2 Namib Lichen Fields

VT 34 Strandveld of West Coast (100%) (Acocks 1953). LR 55 Strandveld Succulent Karoo (100%) (Low & Rebelo 1996).

Distribution Series of small patches on coast-facing hill slopes, about 3.5 km from the coast immediately southeast of Alexander Bay and covering some 75 ha. Altitude 65–94 m.

Vegetation & Landscape Features Mainly on the southwestern slopes of a series of low hills, which form the highest elevation in the otherwise flat or slightly undulating landscape east and south of Alexander Bay. The lichen field generally forms a 10 cm high dense carpet of fruticose individuals. Within the unit, two habitat types can be distinguished which are clearly visible as a well-developed, striking upslope zonation. The upper part of the hill, characterised by gypsum-rich topsoils, is dominated by the orange *Teloschistes capensis*. Further downslope, with gypsum only at a deeper position in the soil, the light green *Ramalina capensis* is dominant. Lichens grow abundantly as epiphytes on the very few angiosperms, such as *Asparagus capensis*. Within the lichen field proper the angiosperm species outnumber lichens, but are less conspicuous. There is a

L. Mucina

Figure 6.4 Dn 2 Namib Lichen Fields: Lichen field at Alexander Bay (Northern Cape) dominated by *Teloschistes capensis*, with a view of Western Gariep Plains Desert in the background. The succulent shrublets in the foreground are *Stoeberia beetzii*.

pronounced occurrence of plants with bodies sunken into the soil in response to summer drought (*Fenestraria rhopalophylla*, *Lithops herrei*, *Euphorbia ramiglans* and *E. stapelioides*). In the rainy season the uptake of water causes expansion and the plants reappear above the soil surface.

Geology & Soils The area straddles the divide between the metavolcanics of the Grootderm Formation and the schists and gneisses (metasediments) of the Oranjemund Formation, both of the Gariep Supergroup (Namibian). The former is mostly covered by quaternary coastal sediments—soft and powdery white clay soils (clay minerals kaolinite or chlorite) with gypsum crusts or gypsum deposits in the topsoil on the mid- to upper slopes and more sandy soils on the lower slopes. Salinity much higher than soils of the surrounding vegetation; some surface pebbles present.

Climate MAP of about 45 mm and rainfall is erratic, predominantly occurring in winter. High frequency of fog, estimated to be greater than 100 days per year, compared to 67 fog days per year measured at the Alexander Bay airport in the lee of the lichen fields outcrop. Fog carried inland by strong winds during the day makes close contact with the ground and the lichens during their period of photosynthesis. MAT 17.2°C. No frost recorded. Although strong southerly winds predominate, the lichen field has no wind-blown sand and lies in a localised corridor outside the general area of moving sand (note that *Ramalina capensis* can grow in habitats with high incidence of sandstorms).

Important Taxa Lichens: *Ramalina capensis* (d), *Teloschistes capensis* (d), *Diploschistes* sp., *Lecidella crystallina*, *Toninia* sp., *Xanthoparmelia walteri*, *Xanthoria flammea*. Leaf- & Stem-succulent Shrubs: *Brownanthus marlothii*, *Pelargonium crithmifolium*, *Psilocaulon dinteri*. Stem-succulent Shrubs: *Euphorbia ramiglans*, *E. stapelioides*, *Sarcocaulon patersonii*. Leaf-succulent Shrubs: *Amphibolia rupis-arcuatae*, *Cephalophyllum ebracteatum*, *Crassula deceptor*, *Drosanthemum luederitzii*, *Eberlanzia sedoides*, *Fenestraria rhopalophylla*, *Lithops herrei*, *Psammophora modesta*, *Pteronia glabrata*, *Stoeberia beetzii*.

Conservation The lichen field near Alexander Bay is unique in its kind in South Africa. Together with the larger, but less dense lichen fields in Namibia, it forms a globally unique vegetation type. Of the lichen fields along the Namib coast, the one near Alexander Bay has the highest biomass and highest species diversity. It therefore deserves a very high conservation status with a target of 100%. The lichen field has been negatively affected by several small roads and off-road vehicle tracks. It is unknown whether the air pollution originating from motor vehicles on the tar road between Port Nolloth and Alexander Bay is causing damage to the lichens. The top of the hill has been used as a quarry and later as a rifle range. The lichen field has recently been declared a Natural Heritage Site and it is protected by a solid fence against off-road driving. The unit should still be regarded as vulnerable if not endangered owing to persisting effects of past damage, possibly insidious pollution effects and very close proximity to other potential human influences, as well as to its remarkably small area.

Remarks Desert lichens are normally negligible in terms of biomass and they are rarely conspicuous. In this unit near Alexander Bay total biomass can attain a very high level of 600g/m^2. Lichen diversity is high, with about 30 species recorded so far. Similar lichen fields dominated by *Teloschistes capensis* covering a much larger area (several hundred square kilometres) in the coastal Central Namib Desert in Namibia, north of Swakopmund, have a much lower biomass and biodiversity (Lalley & Viles 2005). Similar smaller lichen fields, dominated by *Ramalina capensis* are also known from many other places along the coast of the Richtersveld and the Sperrgebiet in Namibia.

References Jürgens & Niebel (1991), Schieferstein & Loris (1992), Jürgens & Niebel-Lohmann (1995), Jürgens (2004), Oguz et al. (2004).

Dn 3 Western Gariep Plains Desert

VT 34 Strandveld of West Coast (60%) (Acocks 1953). LR 57 Lowland Succulent Karoo (58%) (Low & Rebelo 1996).

Distribution On the plains from east of Alexander Bay and south of Grootderm, extending about 15 km to the east and south. The unit borders on Succulent Karoo to the south. Altitude 10–160 m.

Vegetation & Landscape Features The landscape is dominated by plains, although slightly undulating hills and rocky outcrops do occur in places. The flat surface is partly due to its former position below the Atlantic Ocean and partly to being shaped by the frequent sand storms to form an aerodynamic planation surface. The unit is characterised as a sand movement corridor, fed by material from the sandy beaches south of Cape Voltas. Most of the open plains of this unit are seemingly bare of any vegetation, with the exception of scattered individuals of *Sarcocaulon patersonii* or very sparse grasslands of *Stipagrostis geminifolia*. A closer look reveals quite a number of species sunken into or even (for well-defined periods of time) underneath the soil surface (subterrestrial chamaephytes, e.g. *Fenestraria rhopalophylla*). A number of rocky outcrops allow dense stands of many very small succulent chamaephytes, the growth forms of these individuals also shaped by the frequent

sandstorms. With the strong winds and sandblasting, a high frequency of sand-fixing (psammophorous) plants is observed, e.g. *Psammophora modesta* and *Chlorophytum viscosum*.

Geology & Soils Underlying rocks are mainly metasediments and metavolcanics of the Gariep Supergroup (Late Proterozoicum). Quartz-feldspar gneiss, schist, subordinate amphibolite and minor ultramafic rocks are all largely covered by young superficial deposits. Quaternary sediments have developed gypscretes in places, often with high salinity. Generally shallow wind-swept soils with desert pavement are caused by very strong movements of wind-blown sand over the soil surface. Land types Ai and Ia.

Climate MAP 45–55 mm and rainfall erratic, but predominantly in winter. High frequency of fog. Extreme wind speeds and sandblasting from a southern direction and high frequency of sand storms which usually peak in the afternoon. No occurrence of frost. See other similar climate features under Dn 1 Alexander Bay Coastal Duneveld as well as Figure 6.2.

Important Taxa Stem- & Leaf-succulent Shrubs: *Brownanthus marlothii* (d), *Psilocaulon dinteri*. Stem-succulent Shrubs: *Euphorbia stapelioides*, *E. tuberculata*, *Sarcocaulon patersonii*, *Tylecodon schaeferianus*. Leaf-succulent Shrubs: *Cephalophyllum ebracteatum* (d), *Othonna lasiocarpa* (d), *O. sedifolia* (d), *Stoeberia beetzii* (d), *Amphibolia rupis-arcuatae*, *Cheiridopsis brownii*, *C. verrucosa*, *Conophytum saxetanum*, *Crassula deceptor*, *Dracophilus dealbatus*, *Drosanthemum paxianum*, *Eberlanzia sedoides*, *Fenestraria rhopalophylla*, *Juttadinteria deserticola*, *Psammophora modesta*, *Pteronia glabrata*, *Zygophyllum clavatum*, *Z. prismatocarpum*. Other Shrubs: *Asparagus capensis*, *Hermannia gariepina*, *Lycium decumbens*. Graminoid: *Stipagrostis geminifolia* (d). Geophytic Herb: *Pelargonium sibthorpiifolium*. Lichens: *Ramalina capensis* (d), *Teloschistes capensis* (d).

Conservation Target 28%. None conserved in statutory conservation areas. Some 2.6% transformed, almost half of that by roads. The unit is highly sensitive to mechanical destruction of the soil surface. It also occurs at least to some extent in Namibia, where it is protected within the Sperrgebiet National Park. From a South African perspective, this vegetation has a high conservation value as it houses the main populations of some near-endemic species that are more frequently found in Namibia.

Remarks The densest and most diverse lichen field in southern Africa is located near the border on the western edge of this unit, out of reach of the sand movement corridor due to the steep rocky shore at and north of Cape Voltas (see Dn 2 Namib Lichen Fields).

References Jürgens (1991, 1996, 2004), Jürgens & Niebel (1991), Jürgens & Niebel-Lohmann (1995), Jürgens et al. (1997), Oguz (2000), Stöcker (2000), Van Wyk & Smith (2001), Oguz et al. (2004).

Dn 4 Western Gariep Lowland Desert

VT 31 Succulent Karoo (100%) (Acocks 1953). LR 57 Lowland Succulent Karoo (97%) (Low & Rebelo 1996).

Distribution Northwestern Richtersveld, mainly including the lower portion of the large tilted plain of the Annisvlakte pediment west of Kuboes and the hilly mafic lava rock landscape close to Arrisdrif, Brandkaros and Grootderm, close to the lowest reaches of the Orange River, thus extending some 43 km from the southwest to the northeast. The unit borders on Succulent Karoo to the south. Altitude 40–240 m.

Vegetation & Landscape Features On both the eastern plains and in the rocky hilly landscape in the west, sparse low shrubland with mainly leaf- and stem-succulent chamaephytes predominates. The leaf-succulent megachamaephyte (or small nanophanerophyte) *Ruschianthemum gigas* can be dominant or co-dominant with the nanophanerophyte *Euphorbia gummifera* and occurs on a more sandy soil. The low cushions of *Brownanthus pubescens* and the dwarf stem succulent *Euphorbia melanohydrata* show a stronger link to gypsum in the topsoil, while *Brownanthus pseudoschlichtianus* prefers calcretic soils. The vegetation of vast areas is heavily degraded and invaded by the annual *Mesembryanthemum hypertrophicum* (= *Opophytum aquosum*) and the annual or biennial *M. squamulosum* as well as nonsucculent annuals. In the western half of the unit (west of Arrisdrif), high loads of sand originating from the sandveld in the south are transported over rocks by frequent strong winds. This region is characterised by a mosaic of rocky outcrops, formed by mafic lava, and sand-filled valleys and plains. *Euphorbia gummifera* and *Ruschianthemum gigas* are dominant on deep sands above bedrock. Shallower sands are covered by (sometimes well-developed) grasslands with *Stipagrostis geminifolia* or *S. ciliata* dominant, but including *Chlorophytum viscosum*, *Foveolina dichotoma*, *Zygophyllum clavatum* and *Eberlanzia sedoides*. Very dry and shallow sandvelds are sometimes dominated by *Sarcocaulon patersonii*. Rocky outcrops can harbour *Aloe gariepensis* and *Sarcostemma viminale*, together with locally rarer elements like *A. dichotoma* var. *ramosissima* (westernmost population near Brandkaros), *Crassula atropurpurea* var. *cultriformis* and *Othonna clavifolia*. At the interface between rocks and shallow sands, the subterranean chamaephyte *Fenestraria rhopalophylla* with its window leaves is found, but also many geophytes, as in the sandy patches between and on the rocky hills.

N. Jürgens

Figure 6.5 Dn 3 Western Gariep Plains Desert: Gravel pavement shaped by frequent desert sand storms. The yellow flowers belong to the cryptic succulent 'window plant' *Fenestraria rhopalophylla* (Aizoaceae).

N. Jürgens

Figure 6.6 Dn 4 Western Gariep Lowland Desert: Scattered individuals of succulent *Sarcocaulon patersonii* (Geraniaceae) serving as sand traps and forming small, sandy, phytogenic hillocks in the desert 6 km south of Brandkaros in the lower Orange River Valley.

Conservation Target 28%. None conserved in statutory conservation areas in South Africa. The unit also partly occurs in Namibia, where it is protected within the Sperrgebiet National Park. Some 3% transformed, mainly by cultivation (near the Orange River). As with the Dn 3 Western Gariep Plains Desert, this unit is part of a centre of endemism (West Gariep CE; Jürgens 1991), which also includes parts of neighbouring desert units and a part of Namibia. The unit is heavily affected by domestic stock, mainly small stock. Photographs from 1914 show that parts of the Annisvlakte which used to be *Brownanthus pseudoschlichtianus* communities on typical deep loamy-sandy soils are now degraded to poor and saline habitats of *Euphorbia gummifera* and *Mesembryanthemum hypertrophicum*. The unit has also suffered considerable damage from diamond mining. The fate of endangered species like *Euphorbia melanohydrata* depends on the protection on the Namibian side of the Orange River.

Geology & Soils Outcrops of the Grootderm Formation (Gariep Supergroup) consist of chlorite-schist and other metamafic rocks between which filled valleys and plains are found in the west and unconsolidated sandy Quaternary pediments in the east. Biotite granite of the Kuboos Pluton (Cambrian) also occurs in the east. Mispah and Glenrosa soil forms also with red-yellow apedal freely drained soil and high base status are deeper than 300 mm. Gypsum crusts frequent. Along the slope of the large tilted plain of the Annisvlakte, running from the Goariep Mountain (Ploughberg) down to the Orange River, a catena of soil types is observed with silcretes in the upper portion, calcretes in the middle part and gypscretes in the lowest section (Ellis 1980). Land types Fc and Ae.

Climate MAP from about 45–60 mm with winter rains predominant. Fog frequency estimated to be 50–60 days per year. Temperatures are generally relatively mild due to the cooling effect of the nearby Atlantic Ocean, but can be up to 48°C on berg-wind days. No occurrence of frost. Winds and sandstorms are frequent and strong in the western regions of the unit.

Important Taxa Tall Stem- & Leaf-succulent Shrub: *Aloe dichotoma* var. *ramosissima*. Stem- & Leaf-succulent Shrubs: *Brownanthus arenosus* (d), *B. pseudoschlichtianus* (d), *B. pubescens* (d), *Portulacaria pygmaea*. Stem-succulent Shrubs: *Euphorbia gummifera* (d), *E. ephedroides* var. *imminuta*, *E. melanohydrata*, *E. stapelioides*, *Sarcocaulon flavescens*, *S. multifidum*, *S. patersonii*, *Tylecodon schaeferianus*. Leaf-succulent Shrubs: *Ruschianthemum gigas* (d), *Cheiridopsis verrucosa*, *Crassula atropurpurea* var. *cultriformis*, *Didelta carnosa* var. *tomentosa*, *Dracophilus dealbatus*, *Eberlanzia sedoides*, *Fenestraria rhopalophylla*, *Juttadinteria deserticola*, *Othonna clavifolia*, *Psammophora modesta*. Other Shrubs: *Gnidia suavissima*, *Rhyssolobium dumosum*. Graminoids: *Stipagrostis geminifolia* (d), *Centropodia glauca*, *Chaetobromus involucratus* subsp. *involucratus*, *Cladoraphis cyperoides*, *C. spinosa*, *Dregeochloa pumila*, *Stipagrostis ciliata* var. *capensis*, *S. dregeana*, *S. lutescens* var. *lutescens*, *S. schaeferi*, *S. subacaulis*. Geophytic Herbs: *Ammocharis longifolia*, *Babiana namaquensis*, *Chlorophytum viscosum*, *Ferraria schaeferi*, *Hexacyrtis dickiana*, *Strumaria bidentata*. Annual Herb: *Foveolina dichotoma*.

Remarks At a finer mapping resolution, the strongly degraded landscapes east of Arrisdrif could be classified as a separate vegetation unit. A number of species (*Euphorbia herrei*, *E. melanohydrata*, *E. stapelioides*, *Portulacaria pygmaea*, *Psammophora modesta*, *Ruschianthemum gigas*, *Sarcocaulon flavescens*, *S. multifidum)*, endemic to the West Gariep Centre (Jürgens 1991), have their core area of distribution within the Western Gariep Lowlands unit. They also occur to some extent in the adjacent desert units, especially the Dn 5 Western Gariep Hills Desert as well as in the Sperrgebiet National Park in Namibia.

References Van Jaarsveld (1981), Jürgens (1991, 2004), Jürgens et al. (1997), Oguz (2000), Stöcker (2000), Van Wyk & Smith (2001), Oguz et al. (2004), Veste et al. (2004).

Dn 5 Western Gariep Hills Desert

VT 31 Succulent Karoo (66%) (Acocks 1953). LR 56 Upland Succulent Karoo (50%) (Low & Rebelo 1996).

Distribution In the triangle between Sendelingsdrif, Kuboes and Sanddrif in the northern Richtersveld. It shares a border on the east with the Central Richtersveld Mountain Shrubland of the Succulent Karoo Biome. Altitude 60–360 m.

Vegetation & Landscape Features Very heterogeneous broken landscape, mostly hilly but including some smaller and larger plains. Some of the plains are covered by quartz gravel, others by loamy sand or by gravel from different rocks, with strong contrasts between different mosaic elements. The main vegetation unit includes quartz fields, which are covered by dwarf cushions of the *Brownanthus pubescens* community and the *Hartmanthus pergamentaceus* community (Jürgens 2004), the latter being restricted to this unit. The undulating hills, especially on southwestern slopes, are covered by the *Ruschianthemum gigas* desert shrubland community (Jürgens 2004), while rocky outcrops sometimes support populations of the spectacular *Aloe pillansii* (e.g. Cornellskop).

Geology & Soils Metasediments of the Gariep Supergroup dominate this area. They include quartzite, limestone, dolomite,

diamictite and schist which occur in a structurally complex succession, making up the Port Nolloth Group (Namibian). Mispah and Glenrosa soils dominate, with lime generally present in the entire landscape. The dominant land type is Fc.

Climate Predominantly winter rainfall with MAP from about 45–60 mm. High summer maximum temperatures up to 50°C. Frost absent. Fog less frequent than at coast but still estimated to be 40–50 fog days per year, becoming less frequent further up the course of the Orange River.

Important Taxa Succulent Tree: *Aloe pillansii* (d). Stem- & Leaf-succulent Shrubs: *Brownanthus pubescens* (d), *Portulacaria pygmaea.* Stem-succulent Shrubs: *Euphorbia chersina*, *E. ephedroides*, *E. gummifera*, *Sarcocaulon crassicaule*, *S. multifidum.* Leaf-succulent Shrubs: *Ruschia inconspicua* (d), *Ruschianthemum gigas* (d), *Anacampseros papyracea*, *Cephalophyllum numeesensis*, *Cheiridopsis robusta*, *C. verrucosa*, *Didelta carnosa* var. *carnosa*, *Dracophilus dealbatus*, *Eberlanzia ebracteata*, *Hypertelis salsoloides*, *Othonna cylindrica*, *O. opima*, *Ruschia glauca*, *Senecio sarcoides*, *Zygophyllum prismatocarpum*, *Z. schreiberanum.* Low Shrub: *Aptosimum spinescens.* Succulent Herbs: *Mesembryanthemum hypertrophicum*, *M. pellitum*, *Zygophyllum simplex.* Geophytic Herb: *Trachyandra muricata.* Annual Herbs: *Gazania lichtensteinii* (d), *Tripteris microcarpa* (d), *Amellus nanus*, *Gorteria corymbosa, Oncosiphon piluliferum.* Graminoid: *Stipagrostis obtusa.*

Endemic Taxa Leaf-succulent Shrubs: *Astridia citrina*, *Hartmanthus pergamentaceus*.

Conservation Target 28%. Some 11% statutorily conserved in the Richtersveld National Park. About 1% transformed by several active and historical mines. The unit has a high conservation value due to its endemic and other localised species and recommendations have been made to SANParks to incorporate most of it into the Richtersveld National Park. Elsewhere within the unit, Cornellskop has been declared a Natural Heritage Site. The unit also occurs at least to some extent in Namibia where most of it is protected within the Sperrgebiet National Park.

Remarks The distribution of *Brownanthus pubescens*, *Dracophilus dealbatus*, *Ectadium virgatum*, *Euphorbia herrei*, *Juttadinteria deserticola*, *Leipoldtia alborosea*, *Portulacaria pygmaea*, *Psammophora modesta*, *Rhynchosia emarginata*, *Ruschianthemum gigas*, *Sarcocaulon flavescens*, *S. multifidum* and *Zygophyllum schreiberanum* is limited to this unit and the adjacent Western Gariep Lowlands Desert and parts of the Sperrgebiet National Park in Namibia along the northern bank of the Orange River. Although the unit as a whole falls within the Desert Biome, single outcrops at higher altitudes (up to 538 m) and south- to southwest-facing slopes show transition to the adjacent units of the Succulent Karoo.

References Van Jaarsveld (1981), Jürgens (1991, 2004), Schmiedel (1994, 2002a, b, 2004), Jürgens et al. (1997), Schmiedel & Jürgens (1999, 2002, 2004), Van Wyk & Smith (2001).

Gariep Desert

Dg 1 Noms Mountain Desert

VT 33 Namaqualand Broken Veld (100%) (Acocks 1953). LR 56 Upland Succulent Karoo (100%) (Low & Rebelo 1996).

Distribution Northernmost part of the Richtersveld National Park, east of Sendelingsdrif, north of Koeroegab and the Kook River, south of the Orange River. The unit borders on units of the Succulent Karoo Biome to the south. Altitude 100–600 m, with a few higher peaks.

Vegetation & Landscape Features Most of the unit is formed by rugged, generally low mountains with bare rock and very sparse vegetation. Habitats differ according to topography, rock type and climate (see below). On the rocks, succulents like *Aloe dichotoma*, *Ceraria namaquensis*, *Pachypodium namaquanum*, *Tylecodon hallii*, *Commiphora capensis*, *Zygophyllum segmentatum*, *Schwantesia herrei*, but also the rare *Portulacaria armiana* occur. In the valley bottoms, *Dicoma capensis*, *Pharnaceum croceum*, *Dimorphotheca polyptera*, *Mesembryanthemum gariusanum*, *Sesuvium sesuvioides*, *Euphorbia phylloclada*, *Leucophrys mesocoma* and *Stipagrostis namaquensis* are frequent. Relatively more mesic vegetation occurs towards the upper end of the moisture gradient from the hyperarid Orange River Valley to higher altitudes and in some of the gorges.

L. Mucina

Figure 6.7 Dn 5 Western Gariep Hills Desert: Extraordinary spring flower display (2006) with *Gazania lichtensteinii* (pale yellow form), *Amellus nanus* and *Didelta carnosa* var. *carnosa* dominant on hills near Anniskop south of Sendelingsdrif in the Richtersveld. The sparse shrubland contains various species of *Euphorbia, Sarcocaulon, Cephalophyllum, Cheiridopsis* and *Zygophyllum*. The white quartz patches are the habitat of a *Brownanthus pubescens* community. Trees of the rare *Aloe pillansii* are visible in the background.

Geology & Soils Predominantly calc-alkaline, acid and intermediate metavolcanic rocks and quartzitic metasediments of the De Hoop Subgroup (Orange River Group). Also granodiorite, adamellite, leucogranite, tonalite and diorite of the Vioolsdrif Intrusive Suite (Mokolian Erathem) are found. Hardly any deep soils developed. Land type Ic.

Climate MAP approximately 45–60 mm. Variable, transitional climate between winter and summer rainfall. High maximum temperatures, reaching up to 50°C in summer. Frost is very rare, but occurs at higher altitudes. Fog infrequent, particularly in the eastern part of the unit.

Important Taxa Succulent Tree: *Aloe dichotoma*. Small Trees: *Boscia albitrunca*, *Schotia afra*. Stem- & Leaf-succulent Shrubs: *Brownanthus pseudoschlichtianus* (d), *B. nucifer*, *Ceraria namaquensis*, *Psilocaulon subnodosum*, *Senecio sarcoides*, *Tylecodon buchholzianus*, *T.*

hallii. Stem-succulent Shrubs: *Commiphora capensis*, *Euphorbia decussata*, *E. dregeana*, *E. gariepina*, *E. guerichiana*, *E. gummifera*, *E. virosa*, *Kleinia longiflora*, *Othonna arbuscula*, *O. opima*, *Pachypodium namaquanum*, *Sarcocaulon crassicaule.* Leaf-succulent Shrubs: *Aloe gariepensis*, *Ceraria fruticulosa*, *Cheiridopsis robusta*, *Crassula sladenii*, *Drosanthemum floribundum*, *D. inornatum*, *D. otzenianum*, *Eberlanzia ebracteata*, *E. schneideriana*, *Hypertelis salsoloides*, *Leipoldtia grandifolia*, *Portulacaria armiana*, *Prenia tetragona*, *Ruschia leucosperma*, *R. subaphylla*, *Schwantesia herrei*, *Zygophyllum microcarpum*, *Z. prismatocarpum*, *Z. retrofractum*, *Z. segmentatum.* Other Shrubs: *Sisyndite spartea* (d), *Adenolobus gariepensis*, *Aptosimum spinescens*, *Calicorema capitata*, *Chrysocoma schlechteri*, *Dyerophytum africanum*, *Eriocephalus ericoides*, *Euryops multifidus*, *Gaillonia crocyllis*, *Hermannia stricta*, *Hermbstaedtia glauca*, *Indigofera pungens*, *Jamesbrittenia fruticosa*, *Kissenia capensis*, *Monechma mollissimum*, *Montinia caryophyllacea*, *Peliostomum leucorrhizum*, *Pteronia lucilioides.* Graminoids: *Leucophrys mesocoma* (d), *Cyperus marginatus*, *Stipagrostis ciliata*, *S. namaquensis.* Perennial Herbs: *Acanthopsis disperma*, *Dicoma capensis*, *Forsskaolea candida*, *Pharnaceum croceum.* Geophytic Herb: *Trachyandra muricata.* Succulent Herbs: *Mesembryanthemum gariusanum*, *Trianthema triquetra.* Annual Herbs: *Dimorphotheca sinuata*, *Gazania lichtensteinii*, *Leysera tenella*, *Oncosiphon piluliferum*, *Tripteris microcarpa.*

Conservation Least threatened. Target 34%. 100% statutorily conserved in the Richtersveld National Park. The unit has a high conservation value due to high concentration of endemic taxa of the East Gariep CE. Very little transformed but there is some diamond mining at Oenas, close to the Orange River. Domestic grazing is permitted in the park in terms of its status as a contractual park. This unit contains one of the largest aggregations of *Pachypodium namaquanum*. It is also found across the border in Namibia where it is, at least in part, protected within the Ai-Ais National Park.

Remarks Within the unit there is a climatic gradient, running from the hottest and driest parts along the Orange River to the relatively humid transition to the Succulent Karoo north and northwest of the Kodas Peak and the Koeroegabvlakte. In these more humid and cooler parts at higher altitude, vegetation units and taxa belonging to the Succulent Karoo (see Jürgens 2004) also occur (e.g. *Brownanthus pseudoschlichtianus*, *Cheiridopsis robusta*, *Ceraria fruticulosa*). These form scattered patches of SKr 1 Central Richtersveld Mountain Shrubland, which cannot be mapped at present. The unit shares many of the endemics of the East Gariep Centre (Jürgens 1991) e.g. *Brownanthus nucifer*, *Tylecodon hallii*, *Schwantesia herrei*, some *Euphorbia gariepina*, *Mesembryanthemum gariusanum*. *Portulacaria armiana* occurs here and in a very limited area north of the Orange River.

References Van Jaarsveld (1981), Nußbaum (2003), Jürgens (2004).

Dg 2 Richtersberg Mountain Desert

VT 33 Namaqualand Broken Veld (100%) (Acocks 1953). LR 56 Upland Succulent Karoo (100%) (Low & Rebelo 1996).

Distribution Northeastern part of the Richtersveld National Park, south of Kook River and north of the Springbokvlakte and Tatasberg including the mountains of Rooiberg, Richtersberg, Claim Peak and Nabasberg. The unit borders on units of the Succulent Karoo Biome to the west. Altitude 100–882 m (on the summit of Rooiberg).

Vegetation & Landscape Features Rugged mountain ranges with bare rock and valleys some of which (e.g. lower Gannakouriep River) form deep canyons. At high altitudes vegetation cover is sparse; plant cover (including *Commiphora capensis*, *Aloe dichotoma*, *Tylecodon hallii*, *Schwantesia herrei*, *Euphorbia gariepina* and *E. virosa*) is more conspicuous in some gorges and on slopes covered with a mixture of boulders and rubble. On valley bottoms within this vegetation unit sparse grassland mainly with *Leucophrys mesocoma* and *Stipagrostis namaquensis* occur, but also *Stipagrostis obtusa* and *S. ciliata*, after good rains combined with rich populations of opportunistic life forms like *Mesembryanthemum gariusanum* (sometimes flowering in masses), *Dicoma capensis*, *Pharnaceum croceum*, *Dimorphotheca polyptera*, *Sesuvium sesuvioides* and *Euphorbia phylloclada*. But also see remarks under Dg 3 Richtersveld Sheet Wash Desert.

N. Jürgens

Figure 6.8 Dg 1 Noms Mountain Desert: Sheet-wash plains (with scattered *Boscia albitrunca*) form the foreground to the mountainous Noms Desert. *Aloe dichotoma* var. *dichotoma*, *Pachypodium namaquanum*, *Zygophyllum cylindrifolium* and other plants are found on the seemingly barren mountain slopes.

Geology & Soils Granodiorite and adamellite of the Vioolsdrif Suite dominate the area together with the metavolcanics and metasediments of the De Hoop Subgroup of the Orange River Group (Mokolian). Granite of the Tatasberg Pluton (part of the Kuboos-Bremen Suite) also features. Very rocky substrate, with very shallow to no soils. Sands occur in valley bottoms. Land type Ic.

Climate Very variable transitional (winter to summer rainfall) climate. MAP about 45–70 mm. High summer maximum temperatures reach up to 50°C. Frost very rare, but occurs at high altitudes. Fog insignificant. At a new rain meter at 440 m altitude near Claim Peak a MAP of 47.1 mm has been recorded over a six-year period.

Important Taxa Succulent Tree: *Aloe dichotoma* (d). Low Trees: *Boscia albitrunca*, *B. foetida*, *Parkinsonia africana.*

K. Phillips

Figure 6.9 Dg 2 Richtersberg Mountain Desert: A view over the Hidden Valley (part of Dg 3 Richtersveld Sheet Wash Desert) towards Richtersberg as seen from the foot of Tatasberg.

CE of the Nama-Karoo Floristic Region, while the Noms Mountain Desert has a mixture of numerous taxa and minor vegetation units (Jürgens 2004) which are also found in the Succulent Karoo, e.g. in the SKr 1 Central Richtersveld Mountain Shrubland. Dg 2 Richtersberg Mountain Desert is, in contrast, rich in populations of species like *Euphorbia virosa* and *E. gariepina*, which are much less visible in the Noms Mountain Desert. The vegetation of the valley bottoms in the unit could as well be seen as small elements of the vegetation unit Dg 3 Richtersveld Sheet Wash Desert. The unit shares many of the endemics of the East Gariep CE (Jürgens 1991), e.g. *Brownanthus nucifer*, *Tylecodon hallii*, *Schwantesia herrei*, *Euphorbia gariepina* and *Mesembryanthemum gariusanum*.

References Van Jaarsveld (1981), Jürgens (1991, 2004), Nußbaum (2003).

Stem- & Leaf-succulent Shrubs: *Brownanthus pseudoschlichtianus* (d), *Ceraria namaquensis* (d), *Brownanthus nucifer*, *Psilocaulon subnodosum*. Stem-succulent Shrubs: *Euphorbia gariepina* (d), *E. virosa* (d), *Commiphora capensis*, *C. cervifolia*, *Euphorbia decussata*, *E. gummifera*, *E. phylloclada*, *Sarcocaulon crassicaule*. Leaf-succulent Shrubs: *Anacampseros papyracea*, *Ceraria fruticulosa*, *Galenia crystallina*, *Salsola zeyheri*. Other Shrubs: *Sisyndite spartea* (d), *Adenolobus gariepensis*, *Aptosimum spinescens*, *A. tragacanthoides*, *Berkheya fruticosa*, *Cadaba aphylla*, *Calicorema capitata*, *C. squarrosa*, *Eriocephalus ericoides*, *Helichrysum obtusum*, *Kissenia capensis*, *Wellstedia dinteri*. Graminoids: *Stipagrostis ciliata* (d), *S. obtusa* (d), *Enneapogon scaber*. Perennial Herbs: *Acanthopsis disperma*, *Dicoma capensis*, *Forsskaolea candida*, *Pharnaceum croceum*. Geophytic Herbs: *Cyanella hyacinthoides*, *Gladiolus saccatus*, *Trachyandra muricata*. Succulent Herbs: *Mesembryanthemum gariusanum*, *M. pellitum*, *Trianthema triquetra*. Annual Herbs: *Cleome angustifolia* subsp. *diandra*, *Dimorphotheca sinuata*, *Gazania lichtensteinii*, *Helichrysum gariepinum*, *Indigastrum argyroides*, *Oncosiphon piluliferum*, *Trichodesma africanum*, *Tripteris microcarpa*.

Conservation Least threatened. Target 34%. 100% statutorily conserved in the Richtersveld National Park. Also found across the border in Namibia, where it is (at least in part) protected within the Ai-Ais National Park. High conservation value due to its concentration of endemics of the East Gariep CE. Very little transformed. Grazing of private herds is permitted in the park in terms of its status as a contractual park.

Remarks The unit is similar to the neighbouring Dg 1 Noms Mountain Desert. The main difference is that the Dg 2 Richtersberg Mountain Desert is clearly dominated by taxa of the East Gariep

Dg 3 Richtersveld Sheet Wash Desert

VT 33 Namaqualand Broken Veld (93%) (Acocks 1953). LR 56 Upland Succulent Karoo (100%) (Low & Rebelo 1996).

Distribution The unit is represented by many scattered smaller and larger valleys and plains in the northeastern Richtersveld. The largest areas (that can be shown on a map) include the Springbokvlakte, the Maerpoort, parts of the mid-upper reaches of the Abiekwa and Gannakouriep catchments, the lower Kourougab with the Kook River and the lower Kouams River. At a finer scale, many more parts of this unit would become visible in the northeastern parts of the Richtersveld. Altitude approximately 120–600 m.

Vegetation & Landscape Features Sloping, often broad, valley floors, planated by the runoff from rare but strong thunder-

L. Mucina

Figure 6.10 Dg 3 Richtersveld Sheet Wash Desert: The Springbokvlakte in the valley and the Kwaggarug Mountain Desert in the background as viewed from Tatasberg.

N. Jürgens

Figure 6.11 Dg 3 Richtersveld Sheet Wash Desert: *Sisyndite spartea* (Zygophyllaceae) dominating a sheet wash east of the Gannakouriep River in the Richtersveld.

storms and often funnelled by the surrounding bare rock of the mountains. Habitats differ according to water flow and water storage in the soil. Large amounts of runoff water from adjacent hills and mountains can be stored in the deep gravel and sand of the sheet wash valleys, thereby providing a long-lasting water resource. In response, phreatophytes, especially trees such as *Boscia albitrunca*, *B. foetida*, *Schotia afra*, *Parkinsonia africana*, *Maerua gilgii*, *M. schinzii* and *Euclea pseudebenus* are found, mainly on sites sheltered from the destructive forces of the floods. They form a sparse scattered pattern of single trees despite the availability of underground water. The stem-succulent nanophanerophyte *Euphorbia gregaria* is situated in a sheltered (somewhat elevated) part of the lower Springbokvlakte. The force of water flow is often destructive to plants, resulting in a cover of opportunistic life forms on the larger sheet wash plains or valley bottoms. Short-lived plants, after good rains, are *Mesembryanthemum gariusanum* (sometimes flowering in masses), *Sesuvium sesuvioides*, *Dicoma capensis*, *Pharnaceum croceum*, *Dimorphotheca pluvialis*, *D. polyptera*, *Euphorbia phylloclada*, *Monsonia parvifolia* and *Tribulus cristatus*. The longest-lived plants here include grasses (especially the hardy *Leucophrys mesocoma*, *Stipagrostis namaquensis*, *S. obtusa* and *S. ciliata*), but also some other plants such as *Codon royenii*, *Dyerophytum africanum*, *Gaillonia crocyllis*, *Kissenia capensis*, *Monechma mollissimum*, *Prenia tetragona*, *Rogeria longiflora*, *Sisyndite spartea* and *Solanum namaquense*.

Geology & Soils Coarse to fine alluvial sediments created from a variety of rock types mainly of the Vioolsdrif Suite and De Hoop Subgroup (Orange River Group, Mokolian Erathem), but also of the Dwyka Group (Karoo Supergroup), where these glacial deposits cover the older Mokolian rocks. Eroded sediments are shallow to generally deep.

Climate MAP about 45–70 mm. Very variable, transitional climate between winter and summer rainfall, showing a tendency towards summer rainfall in the east (e.g. lower Springbokvlakte). Rare thunderstorms are the most important source of rainfall. High summer maximum temperatures reach 50°C. Frost is very rare, but occurs at high altitudes. A new rain meter near the Tatasberg recorded a MAP of 55 mm over a six-year period.

Important Taxa Small Trees: *Boscia albitrunca*, *B. foetida*, *Euclea pseudebenus*, *Maerua gilgii*, *M. schinzii*, *Parkinsonia africana*, *Schotia afra*. Stem-succulent Shrub: *Euphorbia phylloclada*. Leaf-succulent Shrubs: *Prenia tetragona*, *Zygophyllum microcarpum*. Other Shrubs: *Sisyndite spartea* (d), *Adenolobus gariepensis*, *Calicorema capitata*, *Codon royenii*, *Dyerophytum africanum*, *Gaillonia crocyllis*, *Kissenia capensis*, *Monechma mollissimum*, *Solanum namaquense*. Graminoids: *Leucophrys mesocoma* (d), *Stipagrostis ciliata* (d), *S. namaquensis* (d), *S. obtusa*. Perennial Herbs: *Cleome angustifolia* subsp. *diandra*, *Rogeria longiflora*. Geophytic Herb: *Trachyandra muricata*. Succulent Herb: *Mesembryanthemum gariusanum* (d). Annual Herbs: *Pharnaceum croceum*, *Sesuvium sesuvioides*, *Trichodesma africanum*.

Biogeographically Important Taxon *Euphorbia gregaria*. One large population on the lower Springbokvlakte between the Tatasberg and Grasdrif forms the only known population in South Africa west of Vioolsdrif and is the southwestern outlier of the large distribution area in southern Namibia and the vicinity of the Orange River Valley between Vioolsdrif and Kakamas.

Conservation Least threatened. Target 34%. All mapped parts of this unit are statutorily conserved in the Richtersveld National Park. Very little transformed, but the road network is often biased towards these areas. By definition, this unit is subject to sheet erosion. The unit has a natural high turnover rate and is adapted to frequent disturbance.

Remarks This vegetation unit shares many of the endemics of the East Gariep CE, (e.g. *Mesembryanthemum gariusanum*). The unit shares a number of species with the Dg 6 Helskloof Canyon Desert in which sheet washes also occur. The Springbokvlakte houses the largest patch of the unit and its species composition shows slight deviations from other parts of the unit. Sheet wash features are found in many other Desert units at a wide variety of scales, often at a scale so detailed that it is not possible to separate them out at the mapping scale. Various forms of sheet wash features occur, from those in the winter-rainfall areas to those of the summer-rainfall areas (i.e. Dg 9 Eastern Gariep Plains Desert), from those largely sandy to those with significant amounts of colluvial material (e.g. Dg 6 Helskloof Canyon Desert). These features will have to receive further attention in future mapping work.

References Van Jaarsveld (1981), Nußbaum (2003), Jürgens (2004).

Dg 4 Kwaggarug Mountain Desert

VT 33 Namaqualand Broken Veld (100%) (Acocks 1953). LR 56 Upland Succulent Karoo (100%) (Low & Rebelo 1996).

Distribution South of the Springbokvlakte sheet wash plain and north of the Rosyntjieberge. It includes the Kwaggarug Mountain, the lower slopes of Mount Terror and most of the catchment of the Oudannisiep River. The unit borders on SKr 8 Rosyntjieberg Succulent Shrubland of the Succulent Karoo Biome to the south. Altitude approximately 150–800 m.

Vegetation & Landscape Features Patchy mosaic of isolated hills and mountains, surrounded by limited plains of sheet wash character. Some plains are covered by desert gravel pavements, including quartz fields with their typically associated vegetation; towards the south, on lower slopes of larger mountains with succulent dwarf shrub vegetation.

Geology & Soils Metavolcanics and metasediments (including quartzite) of the Mokolian Orange River Group are most abundant (both the De Hoop Subgroup and Rosyntjieberg Formation are represented). Dwyka diamictite is also present and the Vioolsdrif Suite occurs on the northern and western fringes of the area. Very rocky, with little developed soils or no soil cover. Sands are found in sheet washes and on valley bottoms. Land type Ic.

Climate MAP about 45–70 mm. Transitional, highly variable climate between winter and summer rainfall. No significant occurrence of fog. High summer maximum temperature can reach up to 50°C. Frost is very rare, but occurs at high altitudes.

Important Taxa Succulent Tree: *Aloe dichotoma.* Small Trees: *Boscia albitrunca*, *B. foetida*, *Euclea pseudebenus.* Stem- & Leaf-succulent Shrubs: *Brownanthus pseudoschlichtianus*, *Ceraria namaquensis*, *Psilocaulon subnodosum.* Stem-succulent Shrubs: *Commiphora capensis*, *Euphorbia decussata*, *E. gariepina*, *E. virosa.* Leaf-succulent Shrubs: *Augea capensis*, *Ceraria fruticulosa*, *Conophytum wettsteinii*, *Galenia crystallina*, *Hypertelis salsoloides*, *Zygophyllum decumbens.* Other Shrubs: *Calicorema capitata*, *Dyerophytum africanum*, *Fagonia isotricha* var. *spinescens*, *Gaillonia crocyllis*, *Sisyndite spartea.* Graminoids: *Stipagrostis ciliata*, *S. obtusa.* Perennial Herbs: *Dicoma capensis*, *Forsskaolea candida.* Geophytic Herb: *Trachyandra muricata.* Succulent Herbs: *Mesembryanthemum gariusanum*, *Trianthema triquetra.* Annual Herbs: *Chamaesyce glanduligera*, *Cleome angustifolia* subsp. *diandra*, *Geigeria vigintisquamea.*

Conservation Least threatened. Target of 34% already reached since all units is statutorily conserved in the Richtersveld National Park.

Remarks There is a steep aridity gradient from the border with the Succulent Karoo, through rich Nama-Karoo flora on the higher mountain areas to the species-poor flora in the hyperarid vicinity of the Orange River. This unit shares many of the endemics of the East Gariep CE (*Brownanthus nucifer*, *Euphorbia gariepina*, *Mesembryanthemum gariusanum*, *Schwantesia herrei* and *Tylecodon hallii*).

References Van Jaarsveld (1981), Jürgens (2004).

Dg 5 Kahams Mountain Desert

VT 33 Namaqualand Broken Veld (95%) (Acocks 1953). LR 56 Upland Succulent Karoo (100%) (Low & Rebelo 1996).

Distribution Located between the Stinkfonteinberge basal apron in the west and the Orange River and Helskloof Canyon in the east, and between the Rosyntjieberge in the north and the Rooiberg in the south. The unit borders on units of the Succulent Karoo Biome to the north, south and west. Altitude 150–1 078 m on the summit of the Black Face Mountain.

Vegetation & Landscape Features Highly dissected landscape with rugged mountains with bare rock and very sparse shrubland vegetation becoming somewhat less sparse to the west.

Geology & Soils The granodiorite, adamellite, leucogranite, tonalite and diorite of the Vioolsdrif Suite (Mokolian Erathem) are intruded by syenites and granites of the Richtersveld Suite (Namibian Erathem). These together account for three quarters of the area. Calc-alkaline, acid and metavolcanic rocks and quartzitic metasediments of the De Hoop Subgroup, Orange River Group (Mokolian Erathem) are also significant. Very rocky substrate, with little to no soils. Land type Ib.

Climate MAP about 45–70 mm. Very variable, transitional climate between winter and summer rainfall with tendency towards summer rainfall in the east. Fog absent. Maximum summer temperatures reaching up to 50°C. Frost is very rare, but occurs at higher altitudes. Characterised by steep gradient of increasing aridity from west to east. In the east, hot and dry conditions are typical for the low altitudes along the Orange River, while in the western parts at higher elevations (close to the foothills of the Stinkfonteinberge) the climate is relatively more humid and cooler.

Important Taxa Succulent Tree: *Aloe dichotoma.* Small Trees: *Boscia foetida*, *Maerua gilgii.* Stem- & Leaf-succulent Shrubs: *Brownanthus nucifer* (d), *Ceraria namaquensis* (d), *Brownanthus ciliatus*, *B. pseudoschlichtianus.* Stem-succulent Shrubs: *Euphorbia gariepina*, *E. gummifera*, *E. virosa.* Leaf-succulent Shrub: *Hereroa hesperantha*. Other Shrubs: *Adenolobus gariepensis*, *Dyerophytum africanum*, *Euryops subcarnosus* subsp. *vulgaris*, *Nymania capensis*, *Pelargonium desertorum*, *Petalidium parvifolium*, *Pteronia divaricata*, *P. lucilioides*, *Sisyndite spartea.* Succulent Herb: *Trianthema triquetra*. Annual Herb: *Manulea cheiranthus.*

Conservation Least threatened. Target 34%. About 7% in the far north of the unit is statutorily conserved in the Richtersveld National Park. Although most of the remainder of the unit falls within the Richtersveld Community Conservancy, parts have been heavily impacted by grazing and there is small-scale mining in the unit too. That part of the Orange River that borders this unit is the most popular stretch of the lower

L. Mucina

Figure 6.12 Dg 4 Kwaggarug Mountain Desert: On the Kwaggarug hills immediately across the Springbokvlakte with the much larger Mount Terror and eastern Rosyntjieberg massif (Succulent Karoo) behind.

river for canoeing and rafting with ad hoc overnight camping, which may lightly impact on the vegetation here.

Remarks Although no strict endemics are known, the unit contains a number of endemics of the East Gariep CE, such as *Brownanthus nucifer*, *Euphorbia gariepina*, *Lithops geyeri*, *Mesembryanthemum gariusanum*, *Pelargonium desertorum*, *Sarcocaulon herrei*, *Schwantesia herrei* and *Tylecodon hallii*.

Reference Jürgens (2004).

Dg 6 Helskloof Canyon Desert

VT 33 Namaqualand Broken Veld (100%) (Acocks 1953). LR 56 Upland Succulent Karoo (100%) (Low & Rebelo 1996).

L. Mucina

Figure 6.13 Dg 6 Helskloof Canyon Desert: Sparse vegetation on the valley bottom (sheet wash) in the Helskloof at Modderdrif west of Vioolsdrif, with *Hermbstaedtia glauca*, *Gaillonia crocyllis* and *Zygophyllum* species.

Distribution A small area of canyon landscape in the eastern Richtersveld, between the Nababiepsberge in the east and the Rooiberge in the west, south of Modderdrif on the Orange River and encompassing the lower reaches of the Groen River. Altitude about 160–300 m.

Vegetation & Landscape Features The unit superficially represents the South African equivalent of the Namibian Fish River Canyon. It comprises the canyon floor and initial slopes of the north-south trending canyon, approximately 1 km wide and almost 10 km long. The canyon walls tower 250–350 m above the floor and are more precipitous on the eastern side. Habitat types range from bare rocks and large hammada-like stone areas to dry river beds supporting sparse small trees and shrubs (*Schotia afra*, *Maerua gilgii* and *Adenolobus gariepensis*). On the rocky slopes, scattered populations of succulents such as *Aloe dichotoma*, *Brownanthus ciliatus*, *B. nucifer*, *Ceraria namaquensis*, *Euphorbia gariepina* and *E. virosa* occur. In the debris and washes of the canyon bottom trees such as *Boscia foetida* and *Parkinsonia africana*, or shrubs such as *Sisyndite spartea*, *Calicorema capitata* and *Gaillonia crocyllis* are frequently found.

Geology & Soils Mainly quartzite of the Kuibis Subgroup, Nama Group (Namibian Erathem), with fringes of the area occurring on the metavolcanics and metasediments of the De Hoop Subgroup (Orange River Group, Mokolian Erathem) and also the shale, quartzite and limestone of the Schwarzrand Subgroup (Nama Group, Namibian Erathem). Soil is alluvial sediment with colluvial material in places. Land types Ag and Ae.

Climate MAP roughly 40–60 mm per year tending to peak in late summer, but very variable. Some localised winter water input through drainage from the winter-rainfall area to the south. High summer maximum temperatures often reach 40°C and occasionally 50°C. The bottom of the canyon is one of the hottest environments in the Richtersveld. No incidence of frost.

Important Taxa Succulent Tree: *Aloe dichotoma*. Small Trees: *Boscia albitrunca*, *B. foetida*, *Euclea pseudebenus*, *Maerua gilgii*, *M. schinzii*, *Parkinsonia africana*, *Schotia afra*. Stem- & Leaf-succulent Shrubs: *Ceraria namaquensis* (d), *Brownanthus ciliatus*, *B. nucifer*, *B. pseudoschlichtianus*, *Psilocaulon subnodosum*. Stem-succulent Shrubs: *Euphorbia gariepina* (d), *E. virosa* (d), *Commiphora cervifolia*, *C. gracilifrondosa*, *Euphorbia decussata*, *E. dregeana*, *E. gummifera*, *E. phylloclada*, *Kleinia longiflora*, *Sarcocaulon crassicaule*. Leaf-succulent Dwarf Shrubs: *Cephalophyllum regale*, *Ceraria fruticulosa*, *Cheiridopsis herrei*, *Drosanthemum inornatum*, *D. otzenianum*, *Eberlanzia cyathiformis*, *E. ebracteata*, *Hereroa hesperantha*, *Hypertelis salsoloides*, *Prenia tetragona*, *Ruschia paucipetala*, *Salsola zeyheri*, *Schwantesia herrei*, *Zygophyllum decumbens*, *Z. microcarpum*, *Z. retrofractum*, *Z. rigidum*. Other Shrubs: *Sisyndite spartea* (d), *Adenolobus gariepensis*, *Aptosimum spinescens*, *Blepharis furcata*, *Cadaba aphylla*, *Calicorema capitata*, *Chascanum gariepensis*, *Fagonia capensis*, *F. isotricha* var. *spinescens*, *Gaillonia crocyllis*, *Hermbstaedtia glauca*, *Indigofera pungens*, *Kissenia capensis*, *Limeum aethiopicum* subsp. *namaensis*, *Monechma mollissimum*, *Nymania capensis*. Perennial Herbs: *Codon royenii*, *Forsskaolea candida*, Geophytic Herb: *Bowiea gariepensis*. Succulent Herbs: *Sesuvium sesuvioides*, *Trianthema triquetra*. Annual Herbs: *Geigeria vigintisquamea*, *Pharnaceum croceum*, *Trichodesma africanum*. Graminoid: *Cyperus marginatus*.

Conservation Least threatened. Target 34%. The unit is partly protected in the Nababiep Nature Reserve and has been only very little transformed.

Remarks No species restricted to this unit are known, but the Helskloof is an area where eastern Richtersveld endemics meet with the Bushmanland elements (e.g. *Ozoroa namaquensis*).

Reference Jürgens (2004).

Dg 7 Northern Nababiepsberge Mountain Desert

VT 33 Namaqualand Broken Veld (100%) (Acocks 1953). LR 56 Upland Succulent Karoo (100%) (Low & Rebelo 1996).

Distribution A large plateau of black limestone, south of the Orange River, west of Vioolsdrif, east of Helskloof with a southern boundary 15–20 km south of the river. Altitude about 180–765 m.

Vegetation & Landscape Features Very rocky plateau interrupted by deep gorges. Extreme differences between vegetation on the plateaus and in the gorges. Plateaus often almost

devoid of vegetation. The most important chamaephytes with nevertheless very sparse populations are *Zygophyllum rigidum* and *Z. decumbens*. *Ruschia subaphylla* and *Wellstedia dinteri* are often found on loose rock debris. Depending on local hydrological conditions, the bottoms of the gorges can be covered by woody phreatophytes, which form low gallery shrublands (as in the Helskloof Canyon Desert) or they are bare.

Geology & Soils Mainly shale, quartzite and limestone of the Schwarzrand Subgroup with a small area underlain by the quartzite of the Kuibis Subgroup (both Nama Group, Namibian Erathem). Very rocky with no soils to little and extremely shallow soils. Land type Ic.

Climate MAP about 45–70 mm with rainfall peak in late summer and early autumn. High summer maximum temperatures often higher than 40°C, occasionally reaching 50°C. Frost is very rare, but occurs at high altitudes. See also Figure 6.2.

Important Taxa Succulent Tree: *Aloe dichotoma*. Small Trees: *Boscia albitrunca*, *Euclea pseudebenus*, *Maerua gilgii*, *M. schinzii*. Stem- & Leaf-succulent Shrub: *Brownanthus ciliatus*. Stem-succulent Shrubs: *Commiphora namaensis*, *Euphorbia gariepina*. Leaf-succulent Shrubs: *Ruschia paucipetala* (d), *Zygophyllum decumbens* (d), *Z. rigidum* (d), *Ruschia subaphylla*. Other Shrubs: *Adenolobus gariepensis*, *Calicorema capitata*, *Cryptolepis decidua*, *Hermannia stricta*, *Nymania capensis*, *Petalidium parvifolium*, *Sisyndite spartea*, *Wellstedia dinteri*. Perennial Herbs: *Chascanum garipense*, *Rogeria longiflora*, *Tribulus cristatus*. Succulent Herbs: *Mesembryanthemum gariusanum*, *Trianthema triquetra*.

Conservation Least threatened. Target 34%. None conserved in statutory conservation areas. Large parts mostly inaccessible, hence well preserved.

Remarks The area is not well researched. Possibly it is the most sparsely vegetated of all desert vegetation units.

Reference Jürgens (2004).

Dg 8 Southern Nababiepsberge Mountain Desert

VT 33 Namaqualand Broken Veld (91%) (Acocks 1953). LR 56 Upland Succulent Karoo (100%) (Low & Rebelo 1996).

Distribution South of the Nababiepsberge and north of the Steinkopf Plateau, east of the Groen River and west of the Koubank River. The unit borders on units of the Succulent Karoo Biome to the south (SKr 12 Kosiesberg Succulent Shrubland and SKr 16 Umdaus Mountains Succulent Shrubland). Altitude about 250–984 m (Bluff).

Vegetation & Landscape Features Diverse habitats in a rugged mountain area with plateaus and larger plains and a spectrum of vegetation types, which include relatively tall stands of *Pachypodium namaquanum* and *Aloe dichotoma* on rocky slopes to dwarf succulents on quartz fields and shrubby riverine vegetation in gorges.

Geology & Soils The shales, quartzite and limestone of the Nama Group (Namibian Erathem), both of the Schwarzrand and of the older Kuibis Subgroups. Younger sediments overly granodiorite and adamellite of the Vioolsdrif Intrusive Suite as well as the andesitic lava and acid volcanics of the Haib Subgroup (Orange River Group, Mokolian Erathem). Very rocky with little to no soils. Land type Ic.

Climate Very variable, transitional climate between winter and summer rainfall tending towards summer rainfall in the east. MAP about 50–100 mm. Less extreme maximum temperatures and higher frequency of frost days (<10 per year) than in the neighbouring desert units, especially at higher altitudes.

Important Taxa Succulent Tree: *Aloe dichotoma*. Small Trees: *Boscia albitrunca*, *Euclea pseudebenus*, *Maerua gilgii*, *M. schinzii*, *Schotia afra*. Stem- & Leaf-succulent Shrubs: *Brownanthus ciliatus*, *B. nucifer*, *B. pseudoschlichtianus*, *Ceraria namaquensis*, *Psilocaulon subnodosum*. Stem-succulent Shrubs: *Euphorbia dregeana*, *E. gariepina*, *E. gummifera*, *E. virosa*, *Othonna arbuscula*, *Pachypodium namaquanum*. Leaf-succulent Shrubs: *Drosanthemum inornatum*, *Eberlanzia cyathiformis*, *E. ebracteata*, *Hereroa hesperantha*, *Hypertelis salsoloides*, *Ruschia paucipetala*, *Zygophyllum prismatocarpum*. Other Shrubs: *Adenolobus gariepensis*, *Aptosimum spinescens*, *Cadaba aphylla*, *Calicorema capitata*, *Petalidium parvifolium*. Perennial Herb: *Rogeria longiflora*. Succulent Herbs: *Trianthema triquetra*, *Tripteris microcarpa*.

Conservation Least threatened. Target 34%. None conserved in statutory conservation areas. Large parts are inaccessible.

Remarks This unit shares many of the endemics of the East Gariep CE and neighbouring areas in the south, such as *Brownanthus nucifer*, *Mesembryanthemum gariusanum* and *Cheiridopsis schlechteri*. As with a number of other desert mountain units, substantial altitudinal gradients result in significant climatic and vegetation gradients.

Reference Jürgens (2004).

Dg 9 Eastern Gariep Plains Desert

VT 33 Namaqualand Broken Veld (91%) (Acocks 1953). LR 51 Orange River Nama Karoo (97%) (Low & Rebelo 1996).

Distribution Comprises the sheet wash plains east of the Richtersveld, which lead down to the Orange River at Henkries, Goodhouse, Kabis, Klein Pella/Kambreek and the vicinity of Onseepkans. Also mapped on plains west of Pella to south of Vuurdoodberg Mountain (and Goodhouse) in the west, forming a broad east-west passage between the mountains to the north that fringe or are close to the Orange River and the more broken east-west line of hills and mountains to the south (for example Annakoppies, Grootberg, Witberg, Haramoebberge, Bantamberg and Amankop). Also found at lower reaches of the Kaboep River in the east. This unit also occurs north of the Orange River in Namibia. Altitude roughly 250–900 m.

Vegetation & Landscape Features Often sloping plains, sharply contrasting with the surrounding rocky hills and mountains. Typical wash vegetation in the breaks between the mountains to the Orange River. Grassland dominated by 'white grasses', some spinescent (*Stipagrostis* species), on much of the flats with additional shrubs and herbs in the drainage lines or on more gravelly or loamy soil next to the mountains.

Geology & Soils Quaternary sheet-wash alluvial deposits, sands, deep in places; in south, red-yellow apedal, freely drained soils with a high base status. Land types Ag and Ae.

Climate MAP about 45–80 mm, with rainfall peak in late summer and early autumn, becoming more pronounced eastwards. Summer maximum temperatures are often higher than 40°C, and occasionally reaching 50°C at low altitudes. Frost very rare. Mean monthly maxima and minima for Goodhouse are 44.9°C and 1.9°C for January and July, respectively. See also Figure 6.2.

Important Taxa Small Tree: *Parkinsonia africana*. Stem- & Leaf-succulent Shrubs: *Brownanthus pseudoschlichtianus*, *Psilocaulon subnodosum*. Stem-succulent Shrub: *Euphorbia*

gregaria. Leaf-succulent Shrub: *Zygophyllum microcarpum*. Other Shrubs: *Sisyndite spartea* (d), *Calicorema capitata*, *Gaillonia crocyllis*, *Hermbstaedtia glauca*, *Monechma spartioides*, *Petalidium setosum*. Graminoids: *Stipagrostis brevifolia* (d), *S. ciliata* (d), *Schmidtia kalahariensis*, *Stipagrostis obtusa*. Perennial Herbs: *Codon royenii*, *Rogeria longiflora*. Succulent Herb: *Mesembryanthemum guerichianum*.

Conservation Target 34%. None conserved in statutory conservation areas. Few intact examples of this vegetation remain. Heavy grazing and arid climate combined with the ease of accessibility of the vegetation to stock mean that pastoral activities in the past have significantly altered the structure and composition of vegetation of this unit. In some areas *Prosopis* shows potential to become a serious problem, especially around natural springs or aquifers. Some very restricted areas are cultivated, mainly with date palms and grape vines.

Remarks In the east, this unit is transitional to NKb 3 Bushmanland Arid Grassland to the south. The boundary is diffuse and probably dynamic over time due to shared substrate being modified by land use (e.g. grazing) and medium-term climate changes. The presence and increasing dominance of *Sisyndite spartea* and *Euphorbia gregaria* is indicative of this unit, with these species being characteristically absent from the Bushmanland Arid Grassland unit. In the west the unit forms a transition to SKr 17 Eenriet Plains Succulent Shrubland. Here, the boundary is distinct due to substrate differences (sandy versus rocky) and forms a mosaic of patches, controlled by soil type and distance to inselbergs.

References Van Jaarsveld (1985), Jürgens (1991), Van Wyk & Smith (2001).

Dg 10 Eastern Gariep Rocky Desert

VT 33 Namaqualand Broken Veld (98%) (Acocks 1953). LR 51 Orange River Nama Karoo (99%) (Low & Rebelo 1996).

Distribution All the rocky desert areas along the Orange River, including Groot Pellaberge, Dabenorisberge, Abbasasberge and many smaller mountains between Pella and Vioolsdrif. Also some mountains mapped further south well away from the Orange River such as the Haramoebberge and Witberg. Altitude about 250–1 205 m at the highest peak of the Groot Pella.

P.G. Desmet

Figure 6.14 Dg 9 Eastern Gariep Plains Desert: Sandy sheet-wash plain on the Farm Klein Pella (lower Orange River Valley), with *Euphorbia gregaria*, *Stipagrostis brevifolia* and *S. ciliata*.

Vegetation & Landscape Features Hills and mountains (up to 650 m of relative altitude from their base), mostly with bare rock outcrops and covered with very sparse shrubby vegetation in crevices. Separated by broad sheet-wash plains (Dg 9 Eastern Gariep Plains Desert). Habitats are mainly controlled by topography, aspect, local climate and lithology. On the Groot Pellaberg, for example, there is a sparse shrubland on the southern foothills (with, for example, *Aloe dichotoma*, *Rhigozum trichotomum* and *Petalidium setosum*) and a higher cover of plants in the southern ravines and rocky drainage lines (e.g. *Abutilon pycnodon*, *Asparagus suaveolens*, *Ficus cordata*, *Rhus populifolia* and *R. viminalis*). On the higher southern slopes *Justicia orchioides* is often dominant, with localised grassland directly below steep cliffs (*Enneapogon scaber*, *Triraphis ramosissima* and *Danthoniopsis ramosa*). The south-facing quartzite cliffs and steep slopes support chasmophytes (cremnophytes) such as *Ficus ilicina*, *Aloe dabenorisana* and *Bowiea gariepensis*. On the summits and higher northern slopes there is a much higher preponderance of succulent plants including *Euphorbia avasmontana*, *Aloe dichotoma*, *A. microstigma* subsp. *microstigma*, *Pelargonium aridum* and *Kleinia longiflora*. Succulent plants are also important on the northern foothills and also include *Aloe dichotoma*, *Euphorbia avasmontana*, *Sarcostemma viminale* and the diminutive *Lapidaria margarethae* (Van Jaarsveld 1985).

Geology & Soils In the east mainly leucocratic biotite gneiss and quartz-feldspar gneiss of the Stalhoek Complex and lesser amounts of leucocratic biotite gneiss occur, with intercalations of calc-silicate rocks, mafic gneiss, and a quartzite-schist association of the Hom Subgroup, Bushmanland Group. In the west the area consists of granodiorite, adamellite, leucogranite, tonalite and diorite of the Vioolsdrif Suite and intermediate and acid volcanics of the Haib Subgroup of the Orange River Group (all of the above of Mokolian age). Very rocky substrate, with little or no soils. Land type Ic.

Climate MAP about 45–80 mm with rainfall peak in late summer and early autumn, becoming more pronounced eastwards. Summer maximum temperatures often more than 40°C, occasionally reaching 50°C at low altitudes. Frost is very rare, but occurs at high altitudes.

Important Taxa ([W]Mainly western part, [E]Mainly eastern part) Succulent Tree: *Aloe dichotoma* (d). Small Trees: *Acacia mellifera*, *Boscia albitrunca*, *B. foetida*, *Ehretia rigida*, *Euclea pseudebenus*, *Maerua gilgii*, *Pappea capensis*. Stem-& Leaf-succulent Shrubs: *Brownanthus pseudoschlichtianus*, *Ceraria fruticulosa*, *Psilocaulon subnodosum*, *Ruschia barnardii*. Stem-succulent Shrubs: *Ceraria namaquensis*, *Commiphora capensis*[W], *C. cervifolia*[W], *C. gracilifrondosa*[E], *C. namaensis*, *Euphorbia avasmontana*, *E. friedrichiae*, *E. gariepina*, *E. gregaria*, *E. guerichiana*, *E. virosa*. Leaf-succulent Shrubs: *Aloe dabenorisana*, *A. gariepensis*, *Mesembryanthemum inachabense*, *Prenia tetragona*, *Trianthema parvifolia*, *Tylecodon rubrovenosus*, *Zygophyllum decumbens*, *Z. microcarpum*, *Z. rigidum*. Other Shrubs: *Adenolobus gariepensis*, *Antherothamnus pearsonii*, *Aptosimum tragacanthoides*, *Barleria lancifolia*[E], *B. rigida*, *Cadaba aphylla*, *Calicorema capitata*, *Diospyros acocksii*, *Dyerophytum africanum*, *Eriocephalus scariosus*, *Hermannia stricta*, *Justicia orchioides*, *Monechma mollissimum*,

L.W. Powrie

Figure 6.15 Dg 10 Eastern Gariep Rocky Desert: Pellaberg near Pella with *Euphorbia gregaria*, *Sutera maxii* and *Boscia foetida* subsp. *foetida*.

Petalidium setosum, *Rhigozum obovatum*, *Rhus populifolia*, *Sisyndite spartea*. Graminoids: *Enneapogon scaber*, *Schmidtia kalahariensis*, *Stipagrostis anomala*, *S. ciliata*, *S. obtusa*. Perennial Herbs: *Abutilon pycnodon*, *Chascanum garipense*, *Codon royenii*, *Rogeria longiflora*, *Tribulus cristatus*. Geophytic Herb: *Bowiea gariepensis*. Succulent Herb: *Mesembryanthemum guerichianum*. Annual Herbs: *Cleome angustifolia* subsp. *diandra*, *C. foliosa* var. *lutea*.

Endemic Taxa Small Tree: *Ozoroa namaquensis*. Leaf-succulent Dwarf Shrub: *Tylecodon sulphureus*.

Conservation Target 34%. None conserved in South Africa in statutory conservation areas. This unit also occurs north of the Orange River in Namibia where it is potentially conserved through the ownership of the Farm Tsams by the Namibian Ministry of Environment and Tourism.

Remarks The southernmost mapped mountains are transitional to Bushmanland Inselberg Shrubland. The higher mountains mapped in the unit, especially in the east such as the Pella Mountains, have considerably higher rainfall on the upper slopes with some plant species more characteristic of less hyperarid areas (e.g. *Triraphis ramosissima* on the higher southern slopes and *Euphorbia avasmontana* on the higher and lower northern slopes; Van Jaarsveld 1985). The unit comprises part of the Gariep CE (Van Wyk & Smith 2001). From a phytogeographical point of view, the area belongs to the Namaland Domain of the Nama-Karoo Floristic Region (Jürgens 1991), which approximates the Nama-Karoo Biome as defined by Rutherford & Westfall (1986), but not the Nama-Karoo Biome of Rutherford (1997) as well as in the present work. It may appear necessary to reconsider the current concept of the Eastern Gariep Rocky Desert and to split it into two (possibly near Goodhouse). This step would also corroborate the east-west difference in geology (see above). While the western half is floristically very similar to parts of some of the eastern Richtersveld mountain desert units, the eastern section has many species with a wider savanna- or Kalahari-related distribution.

References Van Jaarsveld (1985), Jürgens (1991, 1997, 2004), Jürgens et al. (1997), Van Wyk & Smith (2001).

10. Credits

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Nama-Karoo Biome 7

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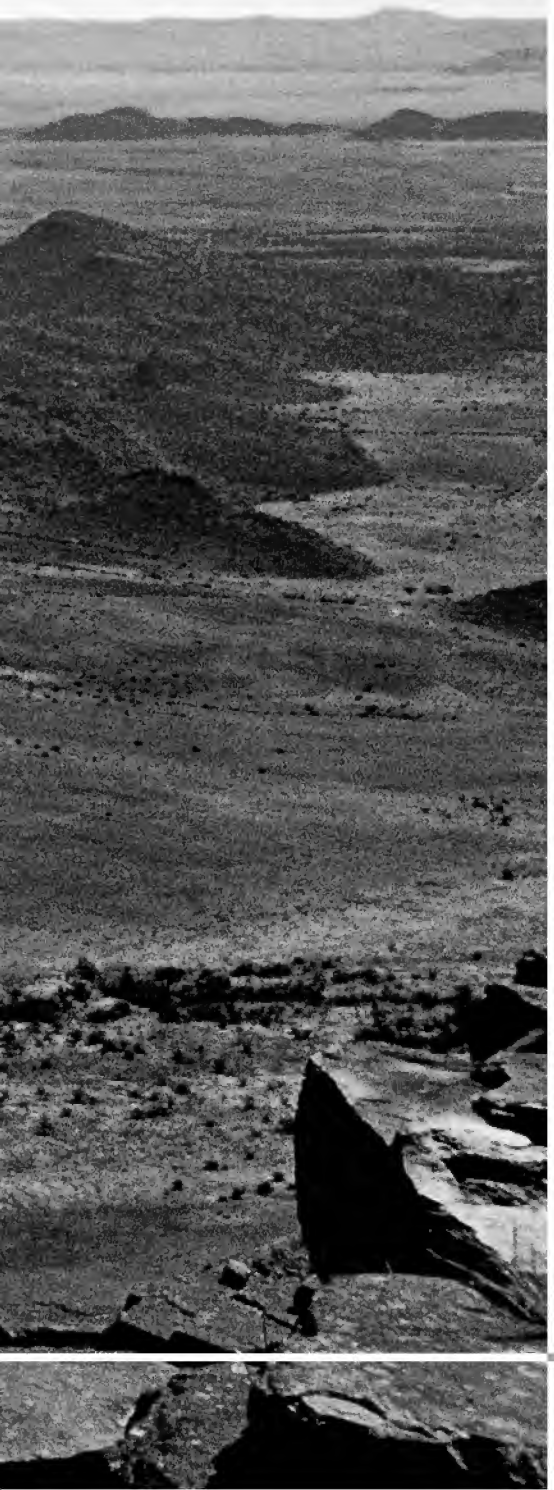

E. Pienaar

Figure 7.1 NKu 4 Eastern Upper Karoo: Typical Nama-Karoo landscape with tafelbergs and butts in the surrounds of Middelburg (Eastern Cape).

1. Introduction: Delimitation and Global Perspective

The Nama-Karoo is a large, landlocked region on the central plateau of the western half of South Africa and extends into southeastern Namibia. The name is derived from the Khoi San word *kuru* meaning 'dry'. Its extensive surface (248 284 km^2 or 19.6% of the area covered by the map) is flanked by six biomes: the Succulent Karoo to the south and west, Desert to the northwest, the arid Kalahari form of the Savanna Biome to the north, Grassland to the northeast, Albany Thicket to the southeast and small parts of Fynbos to the south. The Nama-Karoo has a continental-type climate. In South Africa, only the Desert Biome has a higher variability in annual rainfall and the Kalahari Savanna greater extremes in temperature. The Nama-Karoo has most rainfall in the summer half of the year, especially in late summer.

Biome boundary interfaces between the Nama-Karoo and Desert and Succulent Karoo Biomes have already been discussed under those two biomes. The gradual transitions between the Nama-Karoo and Grassland Biomes on the plains to the northeast make the border between the two particularly difficult to map. However, in the east, the boundary is more distinct, with grassland associated with higher altitudes on mountains, and Nama-Karoo with the plains below.

In addition, the part straddling the middle course of the Orange River was the area that John Acocks asserted had been grassland vegetation and was being invaded by Karoo (see further in Chapter 8 in this book). Much has been written about a second hypothesis of the presumed greater grassiness of the 'Karoo' before heavy grazing by domestic stock (Acocks 1953, Hoffman & Cowling 1990, Bousman & Scott 1994, Meadows 2003). It was probably Acocks's (1953) dramatic map depiction of replacement of Karoo vegetation by desert in much of the western part of the Karoo that caught attention. He also stated that extensive 'near deserts have developed' in the arid west. In 1979 he claimed that large changes in plant composition had also occurred further east in the Nama-Karoo. Dean & Milton (2003) caution against loose interpretation of Acocks's statements that the Karoo has become less grassy. Even in the less arid central and eastern parts of the Nama-Karoo (with higher stocking rates and hence grazing pressure), much of his discussion in 1979 relates to changes in vegetation of main drainage channels. Acocks himself was sometimes ambiguous. In 1979 he stated that 'the striking feature of the Arid Karoo was, and once more is, its grassiness…'. He also stated that his False Succulent Karoo 'in its original condition probably did not differ greatly from the Arid Karoo' veld type (Acocks 1979). In a reanalysis of Acocks's field data, Rutherford et al. (2003) found that the flora of his sample sites in False Succulent Karoo was very similar to that in his Arid Karoo veld type. Other aspects of vegetation dynamics are discussed in the section on Vegetation Structure and Dynamics of this chapter.

The boundaries between the Nama-Karoo and Savanna Biomes are complicated by the substrate pattern at a fine scale. This is the result of the alternation of longitudinal dunes and interdune valleys in the southern Kalahari, with Savanna elements dominant on the dunes but diluted by Nama-Karoo elements (e.g. *Rhigozum trichotomum, Stipagrostis obtusa* and *Pteronia mucronata*; Leistner 1967) in the intervening areas. The shallow rainfall gradient from south to north has not assisted rapid resolution of the debate regarding the status of the vegetation of the southern Kalahari (Leistner 1967, Leistner & Werger 1973). The southern limit of the main dune fields forms the boundary of Nama-Karoo with Savanna in the west (Kalahari Duneveld Bioregion). The boundary to the east (Eastern Kalahari Bushveld Bioregion) corresponds to the area with Savanna generally on deeper consolidated sands or limestone with MAP of greater than 300 mm. Nama-Karoo shares a short border with one of the patches of Savanna in the Eastern Cape.

The southeastern boundary of the Nama-Karoo is complex, interfacing mostly with the Albany Thicket Biome and also with Fynbos, Succulent Karoo, Savanna and Grassland. The Nama-Karoo interface with Albany Thicket does not follow strict substrate lines where Thicket can occur on any substrate (Vlok & Euston-Brown 2002). The boundary between Nama-Karoo and Thicket may also involve a competitive element where 'the process of "thicket building" can be driven forward and backward repeatedly, depending on the occurrence of the disturbance regime' (Vlok & Euston-Brown 2002). Robertson & Palmer (2002) combined various climatic parameters to predict the occurrence of *Portulacaria afra*, an important component of many thicket types. It is, however, not clear which of these variables apply along the Nama-Karoo interface.

Nama-Karoo interfaces with the Fynbos at a few points in the Eastern Cape but is more commonly separated from Fynbos in this area by narrow belts of the Albany Thicket Biome. This vegetation catena corresponds to the sequence from Succulent Karoo through Thicket to Fynbos in some areas to the west. A short border is shared between the Fynbos Biome (represented by arid facies of Roggeveld Shale Renosterveld) and the Nama-Karoo Biome along the western edge of the Great Escarpment.

The present extent of the Nama-Karoo Biome is similar to the spatial extent of the biome of Low & Rebelo (1996), with the most notable difference in the southwestern Free State in the region around Fauresmith, Philippolis, Bethulie and Edenburg which is now recognised as dry facies of the Grassland Biome. This area formed the northeastern portion of Acocks's (1953) False Upper Karoo veld type which Acocks had postulated had formerly been grassland. Independent analysis of Acocks's field data (Rutherford et al. 2003) shows that the flora of this area differs from that of the southwestern portion of this veld type. The climate of this area also corresponds more closely with that of the Grassland Biome (Rutherford & Westfall 1994). Another notable difference to Low & Rebelo (1996) is the intrusion of the Desert Biome in the extreme northwest. This represents an eastern extension of the desert unit of Rutherford (1997) based on confirmed extreme aridity. Another difference is the recognition of Succulent Karoo rather than Nama-Karoo in the Steytlerville Karoo, in what is a climatically marginal area.

Most of the Gordonia Duneveld Bioregion of the Savanna Biome was considered as part of the Nama-Karoo Biome by Rutherford & Westfall (1994). Their approach was not floristic but based on dominant vegetation structure and climate. The life form combination typical of Nama-Karoo occurs in the interdune areas (except the far north) which dominate the much smaller areas of the savanna life form-carrying dunes. The net effect at their defined biome scale was, therefore, Nama-Karoo for this region. Rutherford & Westfall (1994) mapped Nama-Karoo also on the highest plateaus of Lesotho. Again, their biome criteria were structural and based on combinations of co-dominant life-forms, which, with the co-dominance of hemicryptophytes and chamaephytes, translated to Nama-Karoo. The argument for high-altitude physiological drought, rainfall inversion with altitude in high mountains, the rainshadow effect and presence of many plants with xeromorphic adaptations was also put forward. They, however, clearly acknowledged that 'the floristic affinities of much of the vegetation are altogether different…' to Nama-Karoo (Rutherford & Westfall 1994). Their classifica-

tion was not an attempt to place this area within various global schemes of biomes but rather followed a parsimonious system based on variation within the subcontinent following explicit biome criteria as defined by these authors. Rutherford (1997; see also Van Wyk & Smith 2001) has classified the salt pans of Etosha (Namibia) and Madigadigkadi (Botswana) as Nama-Karoo, again based on the grass and shrub combination that fringes the pans which, following their definition, can only be Nama-Karoo. The concept of azonality did not apply in Rutherford & Westfall's (1994) biome map at scale of 1:10 000 000.

Following the Evenari (1985) and Werger (1986) classification of Karoo (which includes Nama-Karoo) as a 'hot desert', analogous biomes can be found in both the northern and southern hemispheres. The climatically and structurally closest biome to the Nama-Karoo on the North American continent is the Chihuahua Desert (MacMahon & Wagner 1985, Brown 1988, MacMahon 1988). The southeastern Australian chenopod shrublands (Goodall 1982, Williams & Calaby 1985) could form a southern-hemisphere analogue of the Nama-Karoo.

2. Climate, Geology and Soils

2.1 Climate

The climate of the Nama-Karoo is essentially continental and is little affected by the ameliorating influences of the oceans. Nama-Karoo is an arid biome. Most of the rivers are nonperennial. Apart from the Orange River and the few permanent streams in the southwest that originate in higher-rainfall neighbouring areas (and in the case of the latter terminate in shallow lakes—Bushmanland Vloere—that dry up in the dry season), the few perennial streams that originate in the Nama-Karoo are limited to the more mesic east, with the Great Fish River of note. MAP ranges from around 70 mm bordering the Desert Biome in the northwest to around 500 mm in the southeast. Most rain falls in late summer (December to April). The low rainfall is unreliable (coefficient of variation of annual rainfall up to 40%) and droughts are unpredictable and sometimes prolonged (Booysen & Rowswell 1983). Rainfall quantity and reliability increase eastwards and the proportion of rain that falls during summer increases to the northeast. In the southwest, rain is brought by unpredictable late summer thunderstorms and occasional inland intrusions of winter high-pressure systems from the west, whereas convectional thunderstorms and southerly movement of the intertropical convergence zone bring reliable summer rain to the northeast of the region (Desmet & Cowling 1999). Summers are hot (mean January maximum >30°C) and

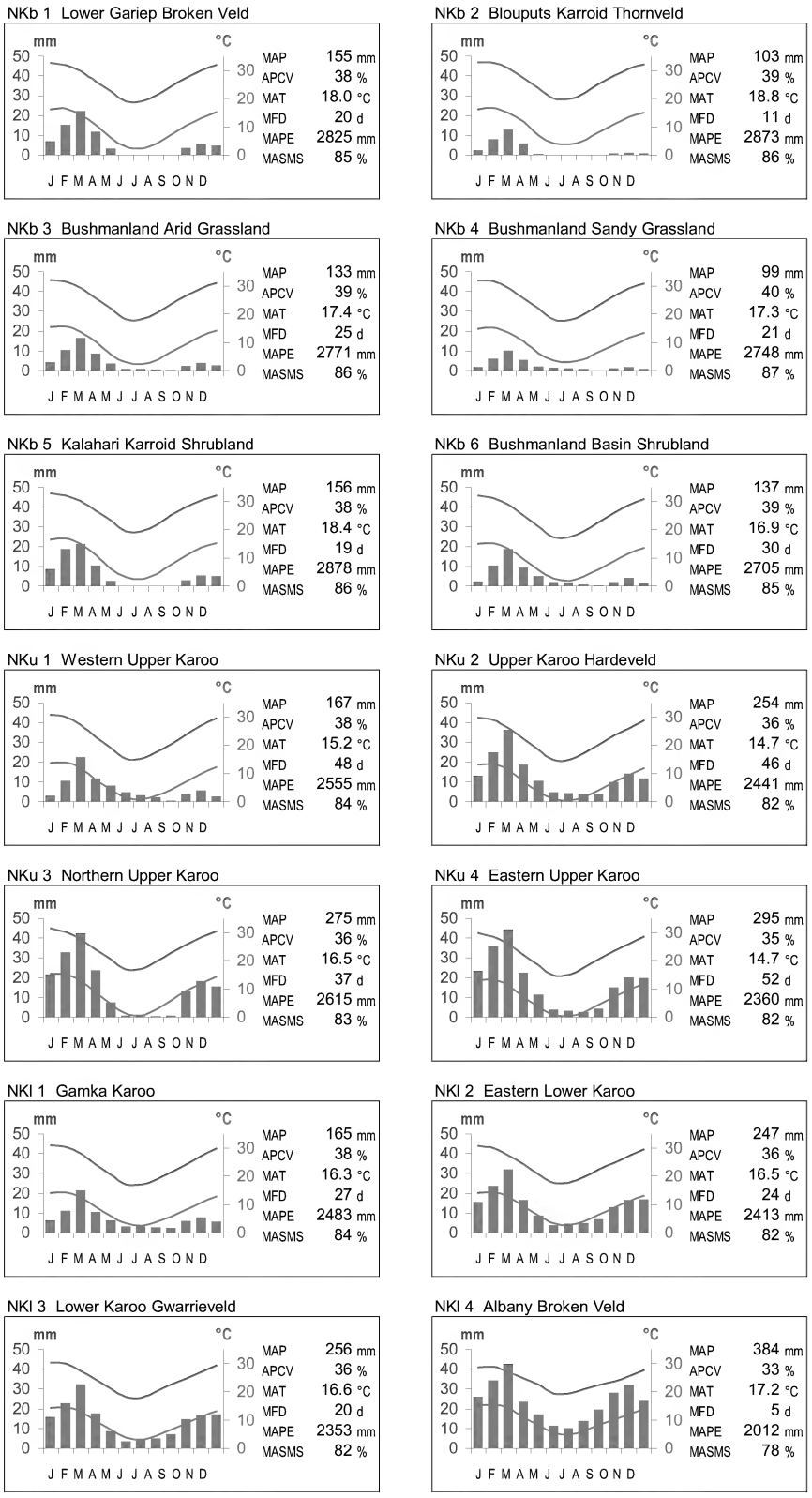

Figure 7.2 Climate diagrams of Nama-Karoo Biome units. Blue bars show the median monthly precipitation. The upper and lower red lines show the mean daily maximum and minimum temperature respectively. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days (days when screen temperature was below 0°C); MAPE: Mean Annual Potential Evaporation; MASMS: Mean Annual Soil Moisture Stress (% of days when evaporative demand was more than double the soil moisture supply).

winters cold (mean July minimum close to zero in the Upper Karoo vegetation types). Temperature extremes range from –5°C in winter to 43°C in summer. Frost occurs in all areas except in the extreme southeast of the biome (Albany Broken Veld) in winter. Dust devils and small whirlwinds are frequent in summer but dust storms are uncommon (Desmet & Cowling 1999).

Rainfall peaks in March in all the vegetation types of Nama-Karoo, and this, together with the onset of frost soon afterwards in the higher-altitude areas, can provide a very short growth season for frost-sensitive species. For example, in the Western Upper Karoo, where very little rainfall is expected in the warm season before March (Figure 7.2), the average first date of heavy frost is in the first half of May (or even late April in the extreme south; Schulze 1997). The shortness of the growing season is further exacerbated in some years when rains arrive even later than usual or frost occurs earlier than average or, most seriously, when both of these occur in the same year.

2.2 Geology and Soils

Underlying the Nama-Karoo is a 3 000 m thick succession of sedimentary rocks. This includes the Cape Supergroup (of marine origin), followed by Dwyka tillites (deposited during southern glaciations 400–300 mya predominantly during the Carboniferous), and then, as southern Africa drifted away from the south pole, by other, fossil-rich, sediments of the Karoo Supergroup (including Ecca and Beaufort Groups) deposited in a great inland sea 300–180 mya. Igneous activity over a significant period 180 myrs ago contributed to local demise of the rich therapsid fauna due to voluminous outpourings of basaltic lava and also caused intrusion of dolerite sills and dykes into Karoo sediments (Meadows & Watkeys 1999). This marked the start of the Gondwanaland break-up (ca. 155 mya), when faulting-initiated erosion processes began shaping the present Karoo landscapes. The Great Escarpment today located 100–200 km from the coast and towering up to 1 000 m over the surrounding landscapes, separates the upper and lower regions of the Nama-Karoo. The escarpment is thought to have been initiated 138 mya during the separation of southern Africa and South America (Ollier & Marker 1985), and the erosion processes initiated then, continue to erode the escarpment, moving it gradually inland. Largely undisturbed by the intense folding in the south that formed the mountains and valleys of the Fynbos and Succulent Karoo Biomes (the Cape Fold Belt), the strata of the Nama-Karoo remained horizontal, giving rise to flat to gently undulating rocky or sandy plains, interrupted by boulder outcrops of igneous origin and flat-topped mesas sculpted by wind and rain. Altitude within the biome varies from 600 to 2 000 m. Much of the terrain in the northwest is interspersed with pans with no outlets.

A detailed soil map, covering most of the Nama-Karoo, is provided by Ellis & Lambrechts (1986). The soils, derived *in situ* under arid conditions from sedimentary rock, igneous intrusions (mainly Jurassic dolerites) and lime-rich evaporite, are generally base-rich, weakly structured and skeletal. Watkeys (1999) divides the Nama-Karoo into several soil regions. In the north from Bushmanland to around Prieska, the most common soils are red and yellow sands to non-swelling clays, generally freely drained. The A-horizon is orthic, as is typical of arid areas in South Africa. Duribank areas are widespread and the coarse soils associated with them may be high in most plant nutrients, especially potassium. In dune areas, such as the Koa River Valley, the soil is deep, uniform, coarse-textured sand poor in plant nutrients. In the interdune areas of Bushmanland, shallow, coarse sand to sandy loam soils of high nutrient status are associated with dorbanks and hardpan calcretes. Further south, in the belt running north of the Great Escarpment, eastwards of Calvinia, most soils are shallow (<300 mm) and weakly structured. Soils overlying the dominant Karoo sediments tend to have lime in upland and bottomland positions. The dolerite outcrops, which are commonly interspersed in this region, develop shallow to moderately deep, calcareous, sandy-clay loams which contain calcrete and calcareous horizons. Around Hanover and further east, duplex soils are dominant, with the clay percentage of the B-horizon more than twice that of the A-horizon. This is associated with the increase in rainfall eastwards. The pattern of soils south of the Great Escarpment generally corresponds to that of the belt north of the escarpment, except that dolerite is absent southwest of Beaufort West. On the Great Escarpment from Fraserburg to around Middelburg, shallow lithosols predominate, with large areas of exposed rocks. Nama-Karoo occurs on the top of the escarpment in the west, but becomes replaced by Grassland at higher altitudes in an easterly direction. The soils developed on dolerites southwest of Middelburg often have a melanic A-horizon and are markedly different from the soils on dolerites in the more arid Carnarvon-Brandvlei area. Soils of the alluvial habitats within the Nama-Karoo are discussed in the chapter on Inland Azonal Vegetation.

3. Biogeography: Origins, Diversity Patterns and Classifications

3.1 Origins of the Nama-Karoo Flora and Vegetation

There is some controversy about the origins of the Karoo flora (Hilton-Taylor 1987, Acocks 1988, Cowling & Hilton-Taylor 1999). Werger (1978a, b) considered the flora to be transitional, with Sudano-Zambezian affinities towards its northern and eastern boundaries, and Cape affinities towards the southwest. Pollen grains from a sediment-filled, volcanic pipe 80 km south of the Orange River suggests that around 70 mya (near the Cretaceous-Tertiary boundary) the climate was warmer (and wetter) than today, with dry forest containing probable forerunners of fynbos that included Proteaceae-, Thymelaeaceae- and Ericaceae-like elements in the understorey (Scholtz 1985). The asteraceous shrub flora that dominates the region today was not present at that time. Low-spine pollen from Tertiary marine sediments off the west coast suggests that Mutisiae-like Asteraceae might have developed afterwards on the subcontinent during the early Tertiary (Scott et al. 1997, Zavada & De Villiers 2000, A. Cadman & L. Scott, unpubl. data). The present more typical modern members of the family with long-spine pollen apparently became prominent only in the late Tertiary (Coetzee 1978, Scott 1995, Scott et al. 1997). The pattern of Asteraceae evolution seems to parallel that found in South America (Barreda 1993). This change in the Late Miocene to biomes that approach the modern types (Coetzee 1978) was possibly in response to global cooling (Shackleton & Kennet 1975) and also resulted in the disappearance of the subtropical characteristics of the vegetation that existed in the Western Cape and the Nama-Karoo as indicated by pollen (Thiergart et al. 1962, Coetzee 1978, Scott 1995) and macrofossils (Bamford & De Wit 1993, De Wit & Bamford 1993). The development of karroid plant and animal communities is likely to have occurred in response to the increase in aridity associated with the growth of the Antarctic Ice Sheet during the late Miocene at a time when the modern winter-rain regime apparently developed in the Cape region (Coetzee 1978). In addition to global cooling during the late Tertiary (Miocene and Pliocene), continental

uplift raised the eastern Nama-Karoo plateau (Partridge 1997). The associated cooling and rainshadow effect could have played a role in the development of the flora and vegetation of the region during the replacement phase of dry woodlands by asteraceous shrubland. However, the absence of a well-dated and continuous fossil record precludes further speculation.

The timing of the evolution of vegetation in the Nama-Karoo and the surrounding region has not been clearly established. Although the Mutisiae-like pollen grains described by Zavada & De Villiers (2000) from marine cores are attributed to the Eocene, evidence for this has not yet been provided. There is uncertainty about how the sediments that contained the pollen should be tied in with unpublished chronometric and palaeontological age estimates of sediment cores (I. MacMillan, De Beers Marine, personal communication, A. Cadman & L. Scott, unpublished data). The proposed timing of the major vegetation change that apparently established the Nama-Karoo in the Late Miocene is also not based on chronometric dates, but on correlation with Shackleton & Kennet's (1975) ocean temperatures (Coetzee 1978). Furthermore, in view of the scarcity of fossil evidence, the original distribution of ancestral taxa to typical Nama-Karoo genera such as *Pentzia*, *Chrysocoma* and *Pteronia* remains unknown.

During the more recent Quaternary period (the last 1.8 myrs) when the present Nama-Karoo regime had already been established, there were widespread fluctuations in climate in the region. Pollen analyses from the Florisbad sediments (in the Grassland Biome to the north near Bloemfontein) suggest that there was a regular alternation of grassland and arid Karoo vegetation in response to fluctuating climates and environments over the last 250 000 years (Van Zinderen Bakker 1989, Grün et al. 1996). The results imply that Karoo vegetation expanded in pulses to cover wider areas than its present range. Van Zinderen Bakker (1957, 1989) and Coetzee (1967) attributed northward expansion of Karoo vegetation into the grassland region to warm, dry events. However, equator-ward shifts of vegetation types should generally be attributed to cooling. Therefore, it is likely that northward expansions of the Nama-Karoo are the result of cool or intermediate conditions where seasonal moisture shifts lowered the relative summer rain proportions and thereby the overall rainfall (Scott & Nyakale 2002). According to this pattern, dry Karoo-like shrublands that included *Elytropappus* or *Stoebe* or both, occupied current grassland areas in the highlands near Noupoort at the Pleistocene to early Holocene transitional period (Bousman et al. 1988). At times during the Late Pleistocene similar vegetation expanded northwards towards Equus Cave near Taung in the southern Kalahari (Scott 1987). At Aliwal North it was relatively grassy at the end of the Pleistocene, although the *Elytropappus/Stoebe* element was present (Coetzee 1967, Scott & Cooremans 1990, Meadows & Watkeys 1999). However, in the drier west of the subcontinent a pollen record from the Richtersveld suggests that Karoo shrub vegetation that included the *Elytropappus/Stoebe* element, occupied the current drier, warmer Succulent Karoo area during the terminal Pleistocene phase (Scott et al. 1995).

During the Holocene (the last 10 000 years) pollen and sedimentary evidence from the broad surrounds of Aliwal North, Noupoort and Beaufort West indicate moisture fluctuations that cause shifts between grass and shrubs suggesting sensitivity to changes in precipitation quantity or seasonality (Bousman et al. 1988, Meadows & Watkeys 1999). The Florisbad site was re-invaded by karroid Asteraceae by ca. 5 000 years BP during an event of apparent cooling and drying, but afterwards summer rains and good grass cover returned ca. 4 000 years BP (Scott & Nyakale 2002).

Northward spreading of Nama-Karoo shrubs at the expense of grasses during the 20th century was attributed to the increased, modern stock farming (Acocks 1953, 1988, see discussion above). However, pollen composition in fossil hyrax dung from the mountains near Noupoort suggests that a process of Asteraceae-spreading started as long as 400 years ago, i.e. before the intensification of stock farming (Bousman & Scott 1994). Furthermore, Hoffman & Cowling (1990) found little evidence that Karoo-spreading was a continuing process during the late 20th century (for further details of this phenomenon, see the chapter on the Grassland Biome).

Provisional observations seem to indicate that organic soils are usually visible in the upper sediments of most erosion gulleys of the eastern Karoo, attesting to the soil development during better moisture conditions in the second half of the Holocene (Bousman et al. 1988, Meadows 1988). However, gullies in the southwestern Karoo (e.g. between Beaufort West and Laingsburg) generally appear to be poor in or devoid of organics. This suggests that this region is typically dry and that marked influx of moisture, whether from the southern winter-rain regime or from the northern monsoon, was not widespread during the Holocene and probably also not during the late Pleistocene.

In view of the general northward shifting of vegetation zones during glacial phases, it is likely that if any arid corridor connections between southern Africa and the rest of Africa developed, they might have been possible during such times. However, according to the available useful sections of the pollen record of the Tswaing Crater (Pretoria Saltpan), Asteraceae increased during some events in the last 200 000 years but the general vegetation remained grassy rather than karroid.

3.2 Diversity and Taxonomic Patterns

The Nama-Karoo flora is not particularly rich, and in comparison with analogous biomes on other continents, does not stand out in contrast to the Succulent Karoo (Cowling et al. 1998). The Nama-Karoo Biome does not contain any centre of endemism (Van Wyk & Smith 2001). Unlike other biomes of southern Africa, local endemism is very low (the highest number of local endemics is concentrated in the Upper Karoo Hardeveld). This might indicate a relatively youthful biome linked to the remarkable geological and environmental homogeneity of the Nama-Karoo, despite genetic plasticity of some families such as Asteraceae—that dominate the Nama-Karoo vegetation. In common with floras of other arid and semi-arid areas, Asteraceae, Fabaceae and Poaceae are dominant families. To the south and west, the Nama-Karoo includes elements of the Succulent Karoo and Fynbos Biomes (Aizoaceae, Asteraceae) and to the north and east, Poaceae, Fabaceae and elements of tropical summer-rainfall floras (Acanthaceae, Capparaceae and Cucurbitaceae) become more prevalent. The contribution of succulent genera of the families Aizoaceae, Crassulaceae, Euphorbiaceae and Apocynaceae to species diversity and cover decreases to the north and east, as the contribution of grasses increases. At generic level, the flora of the Nama-Karoo appears to be a filtered subset of the floras of surrounding biomes (Hilton-Taylor 1987).

Rainfall seasonality and frequency are too unpredictable and winter temperatures too low to enable leaf succulents to dominate as they do under the more reliable winter rainfall of the Succulent Karoo. It is too dry in summer for dominance by perennial grasses alone, and the soils are generally too shallow and the rainfall is too low for trees. Grass dominates aeolian sand patches regardless of rainfall quantity and seasonality in

the Nama-Karoo. Soil type, soil depth and local differences in moisture availability cause abrupt changes in vegetation structure and composition.

At biome or landscape levels, the flora is not particularly species-rich. In 1987, Gibbs Russell estimated that there were 2 147 plant species in a region of 198 500 km^2—the core area of the Nama-Karoo (about 30% of the region). However, there is still no reliable estimate of the size of this flora. At the 0.1 ha scale, plant species density averages 47 (range: 22–76) (Cowling & Hilton-Taylor 1999). There have been a number of attempts to explain the low alpha and beta diversities of the Nama-Karoo. Using J.P.H. Acocks's original data, Hoffman et al. (1994) reported that species richness was negatively correlated with energy in the Karoo (i.e. hot, dry areas supported fewer species than cold, dry or hot, mesic areas within the Karoo). This relationship is also evident at landscape level where small drainage lines support more plant species than surrounding plains (Milton 1990). Cowling & Hilton-Taylor (1999) found that the variables that best explain biome level species richness are the reliability of the rainfall together with the length of the gradient in rainfall quantity. High rates of extinction caused by unreliability of rainfall in the Nama-Karoo may prevent the rapid diversification evident in the Succulent Karoo.

3.3 *Biogeographical and Vegetation Subdivisions*

The Nama-Karoo, as defined by White (1976, 1983) and Werger (1978a, b) in this account, was classified as part of a large, climatologically and floristically heterogeneous phytochorion called the Karoo-Namib Region (Floristic Region in terms of Takhtajan 1986) to accommodate deserts and semideserts of southern Africa. Jürgens (1991), on the basis of an analysis of distribution areas of 1 700 taxa in this region, showed convincingly that two regions should rather be recognised—the *Succulent Karoo Region* and the *Nama Karoo Region* (in Jürgens's original orthography). The latter Region would form part of the Paleotropical Floristic Kingdom (or Afrotropics according to Burgess et al. 2004)—an idea undisputed since the seminal phytogeographical work of White (l.c.). Jürgens (1991) (see also Hilton-Taylor 1987) further suggested that the phytochorion of the Succulent Karoo Region (or rather Succulent Karoo Floristic Region) should form part of the Greater Cape Flora (or rather Cape Floristic Kingdom sensu Takhtajan 1986).

Five of Acocks's (1953) veld type units fall almost entirely within the Nama-Karoo Biome (Central Upper Karoo, Central Lower Karoo, Orange River Broken Veld, Arid Karoo and False Arid Karoo). Major parts of the False Upper Karoo and Karroid Broken Veld, and smaller proportions of the Namaqualand Broken Veld, False Karroid Broken Veld, False Succulent Karoo and Karroid *Danthonia* Mountain Veld fall within the biome. Low & Rebelo (1996) regrouped most of these units and part-units to form six vegetation types in the biome. A numerical analysis of Acocks's original field data (Rutherford et al. 2003) substantiated a number of Acocks's veld types, for example Orange River Broken Veld and Arid Karoo (albeit with modified boundaries). Not supported was the part of the False Succulent Karoo that occurs in the Nama-Karoo. Also not supported were several veld types or parts of veld types in the southeastern Karoo which appeared too finely dissected on Acocks's map. The analysis also supported Acocks's three north-south subdivisions of Arid Karoo. The current vegetation types, which are based on information in addition to Acocks's data, recognise in part these subdivisions of Arid Karoo, with Western Upper Karoo approximating his semisucculent southern form and Bushmanland Basin Shrubland approximating his Driedoring Veld. Acocks's Blomkoolganna Veld in the north joins the current Bushmanland Arid Grassland. Acocks's fragmented veld types on the plains of the southeastern Karoo are reflected in a consolidated Eastern Lower Karoo.

Using data from the climatic responses for southern Africa (Dent et al. 1987) in a topo-moisture analysis, Palmer & Hoffman (1997) defined three geographically distinct biome subdivisions, namely (1) Griqualand West and Bushmanland, (2) the Great Karoo and Central Lower Karoo, and (3) the Upper Karoo and Eastern Cape Midlands. The bioregions of Nama-Karoo approximate these units in the form of Bushmanland, Lower Karoo and Upper Karoo, respectively. Main differences are: the Bushmanland Bioregion does not extend as far east, the Lower Karoo includes the plains around Graaff-Reinet and Aberdeen and the Upper Karoo Bioregion extends further west at higher altitudes.

The Bushmanland Bioregion is separated from the others by having the highest annual rainfall CV (39%), higher mean annual temperature (17.3°C), and low mean annual rainfall (137 mm). This region is dominated by arid shrublands and arid grasslands. The Upper Karoo Bioregion is the largest region and has a higher mean annual rainfall (266 mm), more reliable annual rainfall (CV: 36%) and lowest mean annual temperature (15.4°C). The higher elevation areas comprise montane shrublands, whereas the vast plains contain dwarf shrubland, grassy dwarf shrubland and patches of succulent dwarf shrubland. The Lower Karoo Bioregion is the smallest region and is located south of the Great Escarpment, and is generally climatically intermediate between the other two bioregions of the Nama-Karoo. This region consists of grassy scrub, arid shrubland and riparian woodland in the major river basins.

4. Vegetation Structure and Dynamics

Nama-Karoo is a complex of extensive plains, dominated by low (dwarf) shrubs (generally <1 m tall) intermixed with grasses, succulents, geophytes and annual forbs. Small trees occur only along drainage lines or on rocky outcrops—habitats with special hydropedological microclimatic characteristics.

Despite relatively low floristic diversity, the Nama-Karoo vegetation has a high diversity of plant life forms. These include coexisting ephemerals, annuals, geophytes, C_3 and C_4 grasses, succulents, deciduous and evergreen chamaephytes and trees. This is probably a consequence of an ecotonal and climatically unstable nature of the region (Cowling et al. 1994), which gives no particular life form a consistent advantage. For example, winter rains favour C_3 grasses, succulents and chamaephytes, whereas summer rain and wet years appear to favour C_4 grasses and trees. Interannual variation in rainfall amount and seasonality, and in the frequency and timing of rain events, cause considerable variation in the appearance, structure, cover and productivity of the vegetation (Hoffman et al. 1990, Kellner & Booysen 1999), and may explain the conflicting description of the vegetation of the region given by explorers in the 18th century (Skead 1980).

Natural disturbance factors that drive many vegetation dynamics include many that are linked to human actions and many disturbances interact to modify effects. Factors include: grazing by domestic stock and wild herbivores (including insects), fire, rainfall and runoff (resulting in erosion) and other episodic events such as hailstorms.

Rainfall intensity can be high in the Nama-Karoo with its predominantly convective rain. This, coupled with the generally

low vegetation cover associated with aridity and with grazing pressure by domestic stock over two centuries, raises the potential for soil erosion. In semi-arid environments most of the nutrients are located near the soil surface where they are vulnerable to loss by grazing-induced sheet erosion (Snyman 1999). Soil erosion in the past is best illustrated by the Sterkspruit soil form found in the east of the biome. These soils are deep (>1 m) but grazing-induced erosion of the A-horizon in many places has exposed a relatively impermeable clay-rich B-horizon, resulting in minimal effective depth for rooting (Vorster 1985). Current modelled soil erosion (D. Pretorius, pers. comm.) shows very low to moderate erosion for the Bushmanland areas, mainly moderate erosion in the southern and southeastern Lower Karoo and highest variability in the northeastern Upper Karoo, with erosion varying from very low to high. Erosion in the last-mentioned area takes the form of sheet, gully and rill erosion, whereas in the first-mentioned area, wind erosion can occur (Ellis & Lambrechts 1986). One of the two dominant and shallow soil forms in the Nama-Karoo (Glenrosa) has a low erodibility on flats, gentle rises and apron slopes (Vorster 1985). Erodibility increases on steeper slopes of ridges, hills and mountains, although this is often ameliorated by stony deposits that reduce runoff intensity. The Mispah soil is the other dominant form in Nama-Karoo and is often found in association with Glenrosa. Mispah's erodibility is low. The deeper Hutton form soils are mainly derived from dolerite and old granite and are mainly without structure and have a very low erodibility. In contrast, the Sterkspruit and Swartland soil forms (with structured B-horizons with a high salt content) that are found overwhelmingly in the eastern Nama-Karoo, are very highly and highly erodible respectively, on sloping areas. Plant form can affect erosion. For example, grass cover resists erosion more effectively than shrub cover does (Roux & Opperman 1986). On the other hand, grasses tend to be more sensitive to erosion than shrubs. For example, seedlings of *Sporobolus fimbriatus* are sensitive to erosion, whereas *Psilocaulon coriarium* (= *P. absimile*) can establish itself under extreme conditions of surface disturbance and trampling (Roux & Opperman 1986).

A study of the effect of a hailstorm event in the Western Upper Karoo indicated that the supposed long-term damaging impact of hail on the vegetation of the Nama-Karoo may be seriously overstated (Powrie 1993). At the individual species level, however, plants with fine, brittle branches (*Eriocephalus spinescens* and *Pentzia spinescens*) and a leaf succulent [*Ruschia cradockensis* (= *Eberlanzia horrida*)] may have been adversely affected by hail. Recovery of vegetation after a hail event can be assisted by reducing grazing pressure for at least one year following the damaging event.

Fire in the western, more arid part of the Nama-Karoo is extremely rare. Even in the relatively mesic east, grazing and the highly variable rainfall result in low and discontinuous fuel loads, with only localised burns (Edwards 1984). Occasional fires may occur after successive years of good rainfall in combination with light grazing, resulting in an increased fuel load (Palmer et al. 1999). When it does occur, grass usually increases temporarily (Roux & Vorster 1983a). As a management tool in the dwarf shrublands of the eastern Nama-Karoo, fire should be avoided 'as post-fire recovery is extremely slow' (Palmer et al. 1999). Fire is potentially more common in the east along the southwestern edge of the Grassland Biome including the interface with this biome on the eastern mountains.

The Nama-Karoo region, because of its aridity and unpredictability, favours vagile herbivores such as ostrich (*Struthio camelus*) and springbok (*Antidorcas marsupialis*), nomadic granivorous birds such as finch-larks, lark-like buntings and sand grouse (Dean 1997, 2000), and invertebrates with variable dormancy cued by rain, such as brown locust (*Locustana pardalina*) (Lea 1969, Todd et al. 2002) and Karoo caterpillar (*Loxostege frustralis*) (Annecke & Moran 1977). Populations of these 'boom or bust' species respond rapidly to nutritious post-drought regrowth, flowering and seeding, but when forage quality falls, they must move or die (Skinner et al. 1986, Owen-Smith 1988). Occasional irruptions of brown locust gregaria result in bands of hoppers that create grazing paths which are patchy (0.1–0.5 ha; Brown 1988) but can cover extensive areas (Boshoff 1988). Migrating swarms create grazing site areas at points along their flight path. Grass species are targeted, with only photosynthetically active material selected for grazing. Locust outbreaks do not occur throughout the Nama-Karoo and major outbreak areas seem to occur in the surrounds of Middelburg, De Aar and Hopetown (Erasmus 1988), where grass production potential is relatively high. Opportunistic insect predators are still a feature of Nama-Karoo, and large flocks of storks, bustards and kestrels and wattled starlings follow insect outbreaks (Barber 1880, Dean 2000). Huge herds of springbok periodically built up and moved through the Karoo in search of grazing (Skead 1980, Skinner 1993) until their numbers were diminished by hunting and their movements constrained by fences. Names of farms, hills and rivers in the Nama-Karoo conjure up the ghosts of migrants (buffalo, quagga, hartebeest, eland) and their predators (hyena, leopard, lion), all hunted to near extinction and now largely confined to nature reserves and game farms (Acocks 1979, Dean & Milton 2003). Plant defence against herbivory and adaptations for seed dispersal by mammals are relatively uncommon in the Nama-Karoo, except along rivers and in seasonal pans, suggesting the transient nature of herbivory, except near water where herbivores lingered longer, exerting a greater selective pressure on plants (Milton et al. 1990, Milton 1991).

Since the 19th century, the vast herds of largely migratory ungulates indigenous to the biome have been almost completely replaced by domestic stock (sheep and goats) (Roux & Opperman 1986, Roux & Theron 1987). Following the Fencing Act of 1912, grazing stock was concentrated within farm boundaries. Subsequent subdivisions into camps were carried out on a large scale and stock numbers were increased 'with dire consequences' (Roux & Opperman 1986). The radical change in the grazing regime evoked major changes in the vegetation, especially in respect of species composition (Roux & Theron 1987). Grazing during and immediately after drought periods is a major cause of detrimental change. It appears, for example, that the drought of 1948 to 1950, coupled with heavy continuous grazing, was ultimately responsible for the death of large numbers of palatable plants (Roux & Theron 1987). A number of plant species are poisonous to domestic stock. Examples include species of *Kalanchoe* which cause prussic acid poisoning and *Tribulus terrestris* which is responsible for the most important metabolic disease *geeldikkop* (Vorster & Roux 1983). Game farming does occur in the Karoo, with springbok being overwhelmingly the most important game species (Jooste 1983). Most Nama-Karoo veld is regarded as 'sweet'. The grasses retain their palatability and nutritive value even when mature, and evergreen karroid dwarf shrubs and woody shrubs provide useful browsing in winter (Vorster 1999). The season of grazing can greatly alter plant dominance in the Nama-Karoo. A 30-year trial near Middelburg has shown that paddocks subjected to summer grazing by sheep become dominated by karroid shrubs while those grazed in winter become dominated by perennial grasses. This could be due to seasonal change in grazing preference of the sheep (which favour grasses in summer and herbs in winter) or to a differential response

by grasses to grazing in the growing season (summer) versus grazing in the dormant season (winter) (Palmer et al. 1999). Another analysis of data from these long-term grazing trials showed that plant community change was mostly driven by rainfall variation, but the influence of grazing treatments on longer-lived plants became more important over a longer time (O'Connor & Roux 1995).

Five phases of change in main components in the Upper Karoo over the last couple of centuries and into the future have been hypothesised assuming ongoing overgrazing and mismanagement and summarise some of the above (Roux & Vorster 1983b). Phase 1 is primary degradation in the 19th century and into the first quarter of the 20th century and is characterised by a dramatic decrease in cover of perennial sweet grass through the introduction of domestic stock. Phase 2 (primary denudation, until 1940/50) is characterised by further reduction in palatable species at a rate that could not be offset by the recruitment of these species in this phase. Phase 3 (re-vegetation, until 1970/80) is characterised by improved plant cover but largely in the form of unpalatable shrubs which recruit in the areas laid bare in the previous phase. Phase 4 (secondary degradation, at the time projected until 2000) is characterised by a relatively stable plant cover but with areas dominated by one or two unpalatable species. Phase 5 (desertified phase, projected beyond 2000) would lead to 'near complete degradation' as a result of reduced effectiveness of the rainfall and erosion. Roux & Vorster (1983b) do caution that much variation can occur in these phases and that no discrete breaks between phases should be expected.

5. Status

Very little of the Nama-Karoo has been transformed from natural vegetation to crops, dams, industry or other forms of land use that threaten natural diversity. The dominant land use is the ranching of small stock (wool and mutton sheep, mohair goats), cattle (to the north and east) and game farming with indigenous antelope (Hoffman et al. 1999). Most land is privately or communally owned. Ranches are fenced, but generally large (4 000–15 000 ha) as it takes 10–50 ha of Nama-Karoo to support one large animal unit (roughly equivalent to one head of cattle or seven sheep). Only 0.7% of land is statutorily conserved by national (Karoo and Augrabies Falls National Parks and part of Mountain Zebra National Park) and provincial agencies (Oviston Nature Reserve and parts of the Karoo and Commando Drift Nature Reserves). Additional areas are conserved by local authorities and private land-owners (Hilton-Taylor & Le Roux 1989). The conservation network has not been designed for efficient conservation of vegetation types or fauna. Conservation of birds and other vertebrates within the confines of a protected areas network is impractical given their nomadic response to climatic stochasticity (Dean & Siegfried 1997). The conservation status of the biome and its fauna therefore depends on the condition of the privately owned landscape matrix and the largely non-grazed corridors of vegetation adjacent to the road network. According to a recent assessment by Hoffman & Ashwell (2001), about 60% of the Nama-Karoo landscape has moderately to severely degraded soils and vegetation. Settled lifestyles, provision of drinking water from deep bore holes, virtual extermination of large predators and supplementary feeding of livestock during drought have enabled ranchers to keep animals on the rangeland for periods and at densities that can change vegetation and cause soil erosion.

Analysis of the conservation status of Nama-Karoo relative to the national level is covered in the relevant chapter. Some status issues specific to a vegetation type are given in the description of the vegetation type.

6. Threats

The dynamic behaviour of Nama-Karoo vegetation influences the economy of the region. Grazing by domestic livestock, particularly during the summer growing season of most grasses, reduces the perennial grass component of Nama-Karoo vegetation relative to that of chamaephytes and ephemerals (Roux & Vorster 1983a, O'Connor & Roux 1995, Burke 2002). Interannual fluctuations in grassiness and biomass production influence grazing capacity (Van den Berg 1983, Novellie & Bezuidenhout 1994, O'Connor & Roux 1995, Venter 2001, Du Toit 2002). Prolonged droughts kill a high proportion of perennial plants, rapidly changing vegetation composition in favour of short-lived species with soil-stored seed banks (Henrici 1935a, Milton et al. 1995). Hailstorms cause similar changes at a smaller scale (Powrie 1993). Overgrazing following drought can delay vegetation recovery, exacerbating the effects of subsequent drought (Danckwerts & Stuart-Hill 1988). National and farm-level strategies for managing drought have attracted research and debate for the past century (Anonymous 1923, Booysen & Rowswell 1983) and will doubtless continue to do so, particularly if global warming would desertify the western Nama-Karoo as predicted (Hannah et al. 2002).

One approach to dealing with drought, endorsed by the Department of Agriculture during the 20th century (Turpin & Gill 1928, Whitlock 1961), was the establishment of plantations of alien, drought-hardy forage plants (cactus, saltbush, sisal). Unfortunately, this led to unwanted, bird- and livestock-facilitated invasions of *Prosopis glandulosa, P. juliflora* and *P. velutina* (Richardson et al. 2000) along drainage lines, Australian *Atriplex* species (*A. muelleri, A. nummularia, A. semibaccata*) on saline soils in the Sak River system, and Cactaceae (*Opuntia ficus-indica, O. humifusa, O. rosea, O. aurantiaca, Tephrocactus articulatus*) in the north and east of the biome (Milton et al. 1999, Dean & Milton 2000). Unpalatable (or poisonous) alien herbs such as *Atriplex lindleyi* subsp. *inflata* (Australia), *Salsola kali* and *Limonium sinuatum* (Europe) as well as American *Argemone ochroleuca* and *Schkuhria pinnata* became firmly established, especially in disturbed habitats (along roads, abandoned fields, overgrazed paddocks, sheep pens), diminishing the productivity and value of the land. Further information on alien plants is given under the specific vegetation type where relevant. A number of cogent reasons have been put forward for the likely spread of species of *Prosopis* in South Africa (including other parts of the Nama-Karoo), although other lesser understood factors may halt or reverse its potential for population growth and range expansion (Richardson et al. 2000). The forage availability to domestic stock is increasing by spreading *Prosopis*. However, this spread has a negative influence on the water supply downstream (Richardson et al. 2000).

Mining is not a major threat to habitat conservation in this biome. At present it is confined to igneous and metamorphic geology in the northwest of the region (copper, silver, gypsum, salt). A nuclear waste repository is situated at Vaalputs, Bushmanland, on the western border of the Nama-Karoo (Lloyd 1989a, b), in an area where natural radiation levels from igneous rock and in ground water are dangerously high.

Three climatic change scenarios (developed from GCMs and modelling a doubling of atmospheric CO_2 concentration) applied to South Africa (Rutherford et al. 1999a) indicated that the Nama-Karoo may be expected to exist in its current climate space only in the far eastern part of the existing biome (with

a small part displacing the southwestern Grassland Biome). Individual species, such as *Pentzia incana*, modelled using the same scenarios, indicate a sometimes less drastic reduction in range size in the Nama-Karoo. Rutherford et al. (1999b) attributed the relative vulnerability of the plant species of two national parks in the Nama-Karoo to climate change. Augrabies Falls National Park was indicated to be very vulnerable, with over 40% of its plant species at risk of extinction in the park. The Karoo National Park appeared much better buffered against projected climate change, with less than 1% of its plant species indicated to be at risk of extinction in the Park. Results of biogeoclimatic modelling of species such as *Opuntia ficus-indica* and the *Prosopis* species complex with climate change in the Nama-Karoo are not necessarily conclusive given doubt whether such aliens have yet attained their equilibrium distributions in South Africa (Richardson et al. 2000).

Threats at national level are addressed in the Chapter 17 in this book.

7. Action

The only way to improve the conservation status of the Nama-Karoo is to convince land owners that diverse indigenous vegetation is worth maintaining or conserving. To achieve this there has to be some financial incentive. This could be market-driven (for example farms in better condition should fetch better prices) or driven by national or provincial policy making provision for tax relief to individuals who own areas of particular conservation value and manage them well. The reality is that the Property Rates Bill may force land-owners to farm commercially or to sell their land to those who will do so. It is in the long-term interests of the country to ensure that such incentives for production in a harsh semidesert environment are accompanied by controls that ensure ecological sustainability.

8. Further Research

General reviews that summarise information on the Nama-Karoo environment, flora, fauna and land use include Cowling (1986), Cowling et al. (1986) and Cowling & Roux (1987). Werger (1978b, 1986) synthesised the literature on the phytogeography and phytosociology of the Karoo Biomes (Succulent and Nama), and these subjects have been updated and treated in more detail for the Nama-Karoo in Palmer & Hoffman (1997). Aspects of the environment, evolution, dynamics, utilisation, and conservation status of the Nama-Karoo are covered in a range management guide by Milton & Dean (1996) and in the multi-authored book edited by Dean & Milton (1999).

There has been relatively little in-depth and long-term research on the flora or vegetation of the Nama-Karoo other than that carried out by the Department of Agriculture (and its earlier equivalents) (Henrici 1935b, 1940, Botha et al. 1983, Vorster 1985, O'Connor & Roux 1995). These studies focused on the value of the vegetation for grazing by domestic livestock, and the effects of grazing and drought on vegetation composition. However, the economic costs of land degradation have not been quantified, and this has to be done in order to develop rational conservation and farming policy. The debate around the effects of various grazing systems on the diversity, structure and resilience of Nama-Karoo vegetation still has to be resolved, as does the ecological cost of increasing grazing efficiency by reducing distances between stock watering points. Often, agricultural research emphasis has tended to ignore the total flora in a given area and hence, for example, information on diversity of annuals is scant.

The few phytosociological surveys carried out to date were mainly in protected areas (Palmer 1989, Du Preez & Venter 1990, Hoffman & Cowling 1991, Palmer 1991a, c, Cowling et al. 1994, Novellie & Bezuidenhout 1994, Palmer & Cowling 1994, Rubin & Palmer 1996, Burke 2001). The flora of the central Nama-Karoo remains under-collected (in fact many quarter-degree squares are devoid of collection records), despite the floristically and ecologically interesting inselbergs and outcrops of intrusive igneous rocks, stony plains, and isolated sand pockets in this area. Although ideal conservation networks have been proposed for individual taxa (Lombard 1995, Dean & Siegfried 1997), there is no integrative conservation planning. A multitaxa conservation strategy for the Nama-Karoo should be developed. This should consider the maintenance of the processes that have shaped the vegetation, and allow the vegetation to shift in response to climatic change. The feasibility of developing and maintaining corridors across private and state land therefore has to be investigated.

9. Descriptions of Vegetation Units

Bushmanland & West Griqualand

NKb 1 Lower Gariep Broken Veld

VT 32 Orange River Broken Veld (70%) (Acocks 1953). LR 51 Orange River Nama Karoo (95%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Hardeveld along the Orange River from Onseepkans in the west, including the canyon below the Augrabies Falls and parts of Riemvasmaak and adjacent areas to Keimoes resuming from the Boegoeberg to

L. Mucina

Figure 7.3 NKb 1 Lower Gariep Broken Veld: Ultrametamorphic koppies (locally called 'black hills') surrounded by sandy flats supporting *Stipagrostis hochstetteriana* karoo grasslands (Augrabies Falls National Park near Kakamas, Northern Cape).

around Prieska in the east. A series of inselbergs and koppies occurring between Keimoes and around Kakamas, and the ridge running west of Groblershoop from Karos in the north to around Marydale in the south. The unit also occurs in neighbouring Namibia. Most of the area varies from 400–1 200 m in altitude.

Vegetation & Landscape Features Hills and low mountains, slightly irregular plains but with some rugged terrain (e.g. downstream of the Augrabies Falls) with sparse vegetation dominated by shrubs and dwarf shrubs, with annuals conspicuous, especially in spring, and perennial grasses and herbs. Groups of widely scattered low trees such as *Aloe dichotoma* var. *dichotoma* and *Acacia mellifera* subsp. *detinens* occur on slopes of koppies and on sandy soils of foot slopes respectively.

Geology & Soils The region has a complicate geology: banded iron formation and amphibolites of the Asbestos Hills Subgroup are Vaalian and the carbonates and cherts of the Campbell Group are of the same Era. Metamorphic rocks of the Mokolian Erathem include quartzites and gneisses of the Korannaland Supergroup as well as the Riemvasmaak gneiss. Metamorphosed clastic sediments of the Uitdraai Formation are also Mokolian. The remaining half of the area is composed of many other stratigraphies, metamorphosed sediments and outcrops of the ultrametamorphic rocks of the Namaqualand Metamorphic Complex. The soils are shallow and skeletal (dominant soil forms are Mispah and Glenrosa), typical mainly of Ib and Ic land types, and to a lesser extent also of Fb land type.

Climate MAP ranges from about 70 mm in the west to 240 mm in the east. Mean maximum and minimum monthly temperatures for Kakamas are 41.3°C and –2°C for January and July respectively. Corresponding values for Prieska (near the eastern extremity) are 39.7°C and –4.1°C. Frost incidence varies from less than 10 days of frost per annum in the west to around 30 days in the east. See also climate diagram for NKb 1 Lower Gariep Broken Veld (Figure 7.2).

Important Taxa ([W]Western or [E]Eastern part of this unit only) Succulent Trees: *Aloe dichotoma* var. *dichotoma*. Small Trees: *Acacia mellifera* subsp. *detinens* (d), *Commiphora gracilifrondosa*[W], *Ficus cordata*, *Pappea capensis*[W], *Rhus populifolia*[W], *Ziziphus mucronata* subsp. *mucronata*. Tall Shrubs: *Rhigozum trichotomum* (d), *Adenolobus garipensis*[W], *Antherothamnus pearsonii*[W], *Cadaba aphylla*, *Caesalpinia bracteata, Ehretia rigida* subsp. *rigida*, *Nymania capensis*, *Rhigozum obovatum*[E], *Rhus burchellii*. Epiphytic Semiparasitic Shrub: *Tapinanthus oleifolius*. Succulent Shrubs: *Ceraria namaquensis*, *Cryptolepis decidua*[W], *Euphorbia avasmontana*, *E. gregaria*[W], *Kleinia longiflora*, *Lycium bosciifolium*, *Zygophyllum dregeanum*. Woody Succulent Climber: *Sarcostemma viminale*. Low Shrubs: *Blepharis mitrata* (d), *Aizoon schellenbergii*, *Aptosimum albomarginatum*, *A. lineare*, *A. marlothii*, *Barleria rigida*, *Berkheya spinosissima* subsp. *namaensis*, *Dyerophytum africanum*, *Hermannia spinosa*, *H. vestita*, *Hibiscus elliottiae*, *Indigofera heterotricha*, *Limeum aethiopicum*, *Lophiocarpus polystachyus*, *Monechma spartioides*, *Phaeoptilum spinosum*, *Phyllanthus maderaspatensis*, *Polygala seminuda*, *Ptycholobium biflorum* subsp. *biflorum*, *Sericocoma avolans*, *Solanum capense*, *Stachys burchelliana*, *Talinum arnotii*, *Tetragonia arbuscula*, *Zygophyllum rigidum*. Semiparasitic Shrub: *Thesium lineatum*. Graminoids: *Aristida adscensionis* (d), *Enneapogon desvauxii* (d), *E. scaber* (d), *Eragrostis nindensis* (d), *Stipagrostis obtusa* (d), *S. uniplumis* (d), *Aristida congesta*, *A. engleri*, *Cenchrus ciliaris*, *Digitaria eriantha*, *Enneapogon cenchroides*, *Eragrostis annulata*, *E. lehmanniana*, *E. porosa*, *Schmidtia kalahariensis*, *Setaria verticillata*, *Sporobolus fimbriatus*[E], *Stipagrostis anomala*, *S. ciliata*, *Tragus berteronianus*, *Triraphis ramosissima*[W]. Herbs: *Forsskaolea candida* (d), *Acanthopsis hoffmannseggiana*, *Barleria lichtensteiniana*, *Chamaesyce glanduligera*, *Chascanum garipense*, *Cleome angustifolia* subsp. *diandra*, *Codon royenii*, *Dicoma capensis*, *Garuleum schinzii*[E], *Rogeria longiflora*, *Sesamum capense*, *Tribulus zeyheri*, *Trichodesma africanum*. Succulent Herbs: *Orbea lutea* subsp. *lutea*, *Stapelia flavopurpurea*.

Endemic Taxon Succulent Shrub: *Ruschia pungens*.

Conservation Least threatened. Target 21%. Statutorily conserved in Augrabies Falls National Park (4%). Only a very small part transformed. Erosion is low (58%), very low (27%) and moderate (14%).

References Acocks (1953, 1988), Werger & Coetzee (1977), Bezuidenhout (1996), Zietsman & Bezuidenhout (1999).

NKb 2 Blouputs Karroid Thornveld

VT 33 Namaqualand Broken Veld (100%) (Acocks 1953). LR 51 Orange River Nama Karoo (100%) (Low & Rebelo 1996).

Distribution Northern Cape Province: An irregular belt of relatively flat areas skirting the Lower Gariep Broken Veld from around the Augrabies Falls, westwards on the plain above the Blouputs Valley, through the Narries area to the shallow valleys of Kotie se Laagte and Samoep se Laagte. The unit also occurs in southern Namibia. Altitude varies from 500–800 m.

Vegetation & Landscape Features An open shrubland on slightly undulating rocky plains dominated by patchy occurrences of *Acacia mellifera* subsp. *detinens*. Prominent lower shrubs include *Phaeoptilum spinosum, Boscia foetida* and *Cadaba aphylla,* while the dominant grasses include *Schmidtia kalahariensis* and *Stipagrostis ciliata, S. obtusa* and *S. uniplumis*.

Geology & Soils The geology is dominated by Mokolian gneisses such as those of the Hartbees River Complex and the younger Eendoorn Suite. Schists and quartzites of the

G. Castley

Figure 7.4 NKb 2 Blouputs Karroid Thornveld: *Acacia mellifera* subsp. *detinens* (with accompanying *Stipagrostis obtusa* and *S. uniplumis*) dominating thornveld in the western portion of the Augrabies Falls National Park (Northern Cape).

Bushmanland Group are also significant. Dorbank outcrops at many places and a very dense subdendritic drainage and dissection pattern. The dominating soil forms are Hutton and Mispah—coarse, sandy and shallow (0.1–0.3 m deep). Fb land type dominates the landscape.

Climate Lowest MAP of the vegetation types of the Nama-Karoo (80–120 mm). Seasonal rainfall peaks in March, winters are dry. Incidence of frost is relatively low. See also climate diagram for NKb 2 Blouputs Karroid Thornveld (Figure 7.2).

Important Taxa Small Trees: *Acacia mellifera* subsp. *detinens* (d), *Boscia albitrunca* (d), *B. foetida* subsp. *foetida* (d), *Acacia erioloba*, *Maerua gilgii*. Tall Shrubs: *Rhigozum trichotomum* (d), *Adenolobus garipensis*, *Cadaba aphylla*, *Caesalpinia bracteata*, *Ehretia rigida* subsp. *rigida*, *Nymania capensis*, *Parkinsonia africana*. Epiphytic Semiparasitic Shrub: *Tapinanthus oleifolius*. Low Shrubs: *Phaeoptilum spinosum* (d), *Aptosimum marlothii*, *Berkheya spinosissima* subsp. *namaensis*, *Blepharis mitrata*, *Eriocephalus microphyllus* var. *pubescens*, *Galenia africana*, *Hermannia gariepina*, *H. spinosa*, *H. stricta*, *Indigofera pechuelii*, *Limeum aethiopicum*, *Lophiocarpus polystachyus*, *Microloma incanum*, *Solanum capense*, *Tephrosia dregeana*, *Zygophyllum rigidum*. Succulent Shrubs: *Hoodia gordonii*, *Kleinia longiflora*, *Lycium bosciifolium*, *Salsola rabieana*. Semiparasitic Shrub: *Thesium lineatum*. Herbaceous Climbers: *Coccinia rehmannii*, *Pergularia daemia* var. *leiocarpa*. Herbs: *Amaranthus praetermissus*, *Chascanum garipense*, *Dicoma capensis*, *Forsskaolea candida*, *Limeum myosotis* var. *confusum*, *Mollugo cerviana*, *Sesamum capense*, *Tribulus cristatus*, *T. pterophorus*. Succulent Herbs: *Gisekia pharnacioides*, *Psilocaulon coriarium*, *Trianthema parvifolia*. Graminoids: *Schmidtia kalahariensis* (d), *Stipagrostis ciliata* (d), *S. hochstetteriana* (d), *S. obtusa* (d), *S. uniplumis* (d), *Aristida adscensionis*, *A. congesta*, *Cenchrus ciliaris*, *Enneapogon cenchroides*, *E. desvauxii*, *E. scaber*, *Eragrostis annulata*, *Leucophrys mesocoma*, *Setaria verticillata*, *Tragus racemosus*.

Conservation Least threatened. Target 21%. About 27% of the mapped area under statutory conservation (Augrabies Falls National Park), which is the highest value of any vegetation type in the Nama-Karoo. Only very small area has been transformed. Erosion is low (79%) and very low (21%).

Remarks This vegetation type has the smallest mapped area of all Nama-Karoo vegetation units. It also occurs in some areas in the Riemvasmaak region to the north of the Orange River where it was not mapped because of lack of GIS coverage.

References Werger & Coetzee (1977), Bezuidenhout (1996), Bezuidenhout & Jardine (2001).

L. Mucina

Figure 7.5 NKb 3 Bushmanland Arid Grassland: Arid grassland dominated by species of *Aristida* and *Stipagrostis*, with a solitary koppie supporting vegetation of SKr 19 Bushmanland Inselberg Shrubland (Northern Cape, Aggeneys).

NKb 3 Bushmanland Arid Grassland

VT 29 Arid Karoo and Desert False Grassveld (36%), VT 32 Orange River Broken Veld (36%) (Acocks 1953). LR 51 Orange River Nama Karoo (51%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Spanning about one degree of latitude from around Aggeneys in the west to Prieska in the east. The southern border of the unit is formed by edges of the Bushmanland Basin while in the northwest this vegetation unit borders on desert vegetation (northwest of Aggeneys and Pofadder). The northern border (in the vicinity of Upington) and the eastern border (between Upington and Prieska) are formed with often intermingling units of Lower Gariep Broken Veld, Kalahari Karroid Shrubland and Gordonia Duneveld. Most of the western border is formed by the edge of the Namaqualand hills. Altitude varies mostly from 600–1 200 m.

Vegetation & Landscape Features Extensive to irregular plains on a slightly sloping plateau sparsely vegetated by grassland dominated by white grasses (*Stipagrostis* species) giving this vegetation type the character of semidesert 'steppe'. In places low shrubs of *Salsola* change the vegetation structure. In years of abundant rainfall rich displays of annual herbs can be expected.

Geology & Soils A third of the area is covered by recent (Quaternary) alluvium and calcrete. Superficial deposits of the Kalahari Group are also present in the east. The extensive Palaeozoic diamictites of the Dwyka Group also outcrop in the area as do gneisses and metasediments of Mokolian age. The soils of most of the area are red-yellow apedal soils, freely drained, with a high base status and <300 mm deep, with about one fifth of the area deeper than 300 mm, typical of Ag and Ae land types.

Climate Rainfall largely in late summer/early autumn (major peak) and very variable from year to year. MAP ranges from about 70 mm in the west to 200 mm in the east. Mean maximum and minimum monthly temperatures for Kenhardt are 40.6°C and –3.7°C for January and July respectively. Corresponding values for Pofadder are 38.3°C and –0.6°C. Frost incidence ranges from around 10 frost days per year in the northwest to about 35 days in the east. Whirl winds (dust devils) are common on hot summer days. See also climate diagram for NKb 3 Bushmanland Arid Grassland (Figure 7.2).

Important Taxa ([W]Western and [E]Eastern regions of the unit only) Graminoids: *Aristida adscensionis* (d), *A. congesta* (d), *Enneapogon desvauxii* (d), *Eragrostis nindensis* (d), *Schmidtia kalahariensis* (d), *Stipagrostis ciliata* (d), *S. obtusa* (d), *Cenchrus ciliaris*, *Enneapogon scaber*, *Eragrostis annulata*[E], *E. porosa*[E], *E. procumbens*, *Panicum lanipes*[E], *Setaria verticillata*[E], *Sporobolus nervosus*, *Stipagrostis brevifolia*[W], *S. uniplumis*, *Tragus berte-*

ronianus, *T. racemosus*[E]. Small Trees: *Acacia mellifera* subsp. *detinens*[E], *Boscia foetida* subsp. *foetida*. Tall Shrubs: *Lycium cinereum* (d), *Rhigozum trichotomum* (d), *Cadaba aphylla*, *Parkinsonia africana*. Low Shrubs: *Aptosimum spinescens* (d), *Hermannia spinosa* (d), *Pentzia spinescens* (d), *Aizoon asbestinum*[E], *A. schellenbergii*[E], *Aptosimum elongatum*, *A. lineare*[E], *A. marlothii*[E], *Barleria rigida*, *Berkheya annectens*, *Blepharis mitrata*, *Eriocephalus ambiguus*, *E. spinescens*, *Limeum aethiopicum*, *Lophiocarpus polystachyus*, *Monechma incanum*, *M. spartioides*, *Pentzia pinnatisecta*, *Phaeoptilum spinosum*[E], *Polygala seminuda*, *Pteronia leucoclada*, *P. mucronata*, *P. sordida*, *Rosenia humilis*, *Senecio niveus*, *Sericocoma avolans*, *Solanum capense*, *Talinum arnotii*[E], *Tetragonia arbuscula*, *Zygophyllum microphyllum*. Succulent Shrubs: *Kleinia longiflora*, *Lycium bosciifolium*, *Salsola tuberculata*, *S. glabrescens*. Herbs: *Acanthopsis hoffmannseggiana*, *Aizoon canariense*, *Amaranthus praetermissus*, *Barleria lichtensteiniana*[E], *Chamaesyce inaequilatera*, *Dicoma capensis*, *Indigastrum argyraeum*, *Lotononis platycarpa*, *Sesamum capense*, *Tribulus pterophorus*, *T. terrestris*, *Vahlia capensis*. Succulent Herbs: *Gisekia pharnacioides*[E], *Psilocaulon coriarium*, *Trianthema parvifolia*. Geophytic Herb: *Moraea venenata*.

Biogeographically Important Taxon (Bushmanland endemic) Succulent Herb: *Tridentea dwequensis*.

Endemic Taxa Succulent Shrubs: *Dinteranthus pole-evansii*, *Larryleachia dinteri*, *L. marlothii*, *Ruschia kenhardtensis*. Herbs: *Lotononis oligocephala*, *Nemesia maxii*.

Conservation Least threatened. Target 21%. Only small patches statutorily conserved in Augrabies Falls National Park and Goegab Nature Reserve. Very little of the area has been transformed. Erosion is very low (60%) and low (33%).

Remarks This unit has a large longitudinal extent, with some species common in only part of the unit. Further research may lead to the split of this unit at a later stage.

References Acocks (1953, 1988), Du Toit (1996), L. Mucina (unpubl. data).

NKb 4 Bushmanland Sandy Grassland

VT 29 Arid Karoo and Desert False Grassveld (80%) (Acocks 1953). LR 49 Bushmanland Nama Karoo (71%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Surrounds of Aggeneys (northern Bushmanland) and a few isolated patches south of Copperton on the eastern edge of the Bushmanland Basin suggesting the course of the paleoriverine system of the Orange River and its tributaries. The largest continuous patch of this vegetation type fills the shallow valley of the intermittent Koa River southeast and west of Aggeneys. Altitude varies mostly from 500–1 200 m.

Vegetation & Landscape Features Dense, sandy grassland plains with dominating white grasses (*Stipagrostis, Schmidtia*) and abundant drought-resistant shrubs. After rainy winters rich displays of ephemeral spring flora (*Grielum humifusum, Gazania lichtensteinii*) can occur.

Geology & Soils Mostly Quaternary sediments (sand, calcrete) with some contribution of the pre-Pleistocene Kalahari Group sediments in the east. Typically the surface is covered by red sands >300 mm deep, forming dunes in places. Af land type dominates.

Climate Major rainfall peak between February and April and a minor peak in November. MAP ranges from about 70–110 mm. See also climate diagram for NKb 4 Bushmanland Sandy Grassland (Figure 7.2).

Important Taxa Graminoids: *Schmidtia kalahariensis* (d), *Stipagrostis brevifolia* (d), *S. ciliata* (d), *S. obtusa* (d), *Aristida adscensionis*, *A. congesta*, *Centropodia glauca*, *Enneapogon desvauxii*, *Stipagrostis anomala*. Herbs: *Gazania lichtensteinii* (d), *Grielum humifusum* (d), *Tribulus zeyheri* (d), *Dicoma capensis*, *Hirpicium echinus*, *Manulea nervosa*, *Requienia sphaerosperma*, *Sesamum capense*. Succulent Herb: *Crassula muscosa*. Tall Shrubs: *Rhigozum trichotomum*, *Sisyndite spartea*. Low Shrubs: *Zygophyllum microphyllum* (d), *Barleria rigida*, *Berkheya spinosissima* subsp. *namaensis*, *Eriocephalus microphyllus* var. *pubescens*, *E. pauperrimus*, *Galenia fruticosa*, *Hermannia spinosa*, *Monechma incanum*, *Peliostomum leucorrhizum*, *Pentzia spinescens*, *Plinthus karooicus*, *Pteronia mucronata*, *P. sordida*, *Rosenia humilis*, *Tetragonia arbuscula*. Succulent Shrubs: *Aridaria noctiflora* subsp. *straminea*, *Lycium bosciifolium*, *Ruschia robusta*, *Salsola tuberculata*, *Senecio cotyledonis*, *Zygophyllum flexuosum*, *Z. foetidum*. Woody Succulent Climber: *Sarcostemma viminale*.

Conservation Least threatened. Target 21%. None conserved in statutory conservation areas. Very little of the area has been transformed. The alien shrub *Prosopis* sp. can be seen as a threat. Erosion is very low (82%) or moderate (17%).

Remarks This is a poorly known vegetation unit, separable from the surrounding units by its deep sands, often with red sand dunes. The occurrence of elements such as *Acacia erioloba, Schmidtia kalahariensis* and *Tribulus zeyheri* suggests similarity to southern Kalahari duneveld flora.

References Anderson & Van Heerden (2000), L. Mucina (unpubl. data).

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Figure 7.6 NKb 4 Bushmanland Sandy Grassland: Dry shrubby grassland dominated by *Stipagrostis obtusa* and *S. brevifolia* on deep sands of the ancient Koa River wash near Aggeneys (Northern Cape).

NKb 5 Kalahari Karroid Shrubland

VT 16 Kalahari Thornveld and Shrub Bushveld (60%) (Acocks 1953). LR 29 Karroid Kalahari Bushveld (61%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Typically forming belts alternating with belts of Gordonia Duneveld on plains northwest of Upington through Lutzputs and Noenieput to the Rietfontein/Mier area in the north. Other patches occur around Kakamas and north of Groblershoop. The unit is also found in the neighbouring Namibia. Altitude varies mostly from 700–1 100 m.

Vegetation & Landscape Features Low karroid shrubland on flat, gravel plains. Karoo-related elements (shrubs) meet here with northern floristic elements, indicating a transition to the Kalahari region and sandy soils.

Geology & Soils Cenozoic Kalahari Group sands and small patches also on calcrete outcrops and screes on scarps of intermittent rivers (mekgacha). In places Dwyka Group tillites outcrop. The soils are deep (>300 mm), red-yellow, apedal, freely drained, with a high base status, typical of Ae land type.

Climate MAP ranges from about 100–200 mm and most rain falls in late summer and early autumn. Winters are particularly dry, with lowest winter relative humidity compared to other Nama-Karoo types. Mean maximum and minimum monthly temperatures in Upington are 39.5°C and –4.2°C for January and July, respectively. Solar radiation is high and in winter is higher than in any other vegetation type of the Nama-Karoo. See also climate diagram for NKb 5 Kalahari Karroid Shrubland (Figure 7.2).

Important Taxa Small Trees: *Acacia mellifera* subsp. *detinens* (d), *Parkinsonia africana* (d), *Boscia foetida* subsp. *foetida*. Tall Shrub: *Rhigozum trichotomum* (d). Epiphytic Semiparasitic Shrub: *Tapinanthus oleifolius*. Low Shrubs: *Hermannia spinosa* (d), *Limeum aethiopicum* (d), *Phaeoptilum spinosum* (d), *Aizoon schellenbergii*, *Aptosimum albomarginatum*, *A. lineare*, *A. marlothii*, *A. spinescens*, *Barleria rigida*, *Hermannia modesta*, *Indigofera heterotricha*, *Leucosphaera bainesii*, *Monechma genistifolium* subsp. *genistifolium*, *Phyllanthus maderaspatensis*, *Polygala seminuda*, *Ptycholobium biflorum* subsp. *biflorum*, *Sericocoma avolans*, *Solanum capense*, *Tephrosia dregeana*. Herbs: *Dicoma capensis* (d), *Chamaesyce inaequilatera* (d), *Amaranthus praetermissus*, *Barleria lichtensteiniana*, *Chamaesyce glanduligera*. *Chascanum garipense*, *Cleome angustifolia* subsp. *diandra*, *Cucumis africanus*, *Geigeria ornativa*, *Hermannia abrotanoides*, *Indigastrum argyraeum*, *Indigofera alternans*, *I. auricoma*, *Kohautia cynanchica*, *Limeum argute-carinatum*, *Mollugo cerviana*, *Monsonia umbellata*, *Sesamum capense*, *Tribulus cristatus*, *T. pterophorus*, *T. terrestris*. Succulent Herbs: *Gisekia africana*, *G. pharnacioides*, *Trianthema parvifolia*. Graminoids: *Aristida adscensionis* (d), *Enneapogon desvauxii* (d), *E. scaber* (d), *Stipagrostis obtusa* (d), *Aristida congesta*, *Enneapogon cenchroides*, *Eragrostis annulata*, *E. homomalla*, *E. porosa*, *Schmidtia kalahariensis*, *Stipagrostis anomala*, *S. ciliata*, *S. hochstetteriana*, *S. uniplumis*, *Tragus berteronianus*, *T. racemosus*.

Biogeographically Important Taxon (Southwestern distribution limit) Graminoid: *Dinebra retroflexa*.

Conservation Least threatened. Target 21%. Very little statutorily conserved in Augrabies Falls National Park. Although only a small area has been transformed many of the belts of this type were preferred routes for early roads, thus promoting the introduction of alien plants (about a quarter of the unit has scattered *Prosopis* species). Erosion is very low (94%).

Remarks Vegetation of this mapping unit shows transitional features between the Kalahari proper (Savanna Biome) and the northern Nama-Karoo.

References Leistner (1967), Leistner & Werger (1973), Werger & Leistner (1975), Werger (1978b, 1986), Werger et al. (1979), Bezuidenhout (1996), Werger & Coetzee (1977).

NKb 6 Bushmanland Basin Shrubland

VT 29 Arid Karoo and Desert False Grassveld (88%) (Acocks 1953). LR 49 Bushmanland Nama Karoo (92%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Large Bushmanland Basin centred on Brandvlei and Van Wyksvlei area, spanning Granaatboskolk in the west to Copperton in the east, and Kenhardt vicinity in the north to Williston vicinity in the south. Altitude ranges mostly from 800–1 200 m.

Vegetation & Landscape Features Slightly irregular plains with dwarf shrubland dominated by a mixture of low sturdy and spiny (and sometimes also succulent) shrubs (*Rhigozum*, *Salsola*, *Pentzia*, *Eriocephalus*), 'white' grasses (*Stipagrostis*) and in years of high rainfall also by abundant annuals such as species of *Gazania* and *Leysera*.

Geology & Soils Mudstones and shales of Ecca Group (Prince Albert and Volksrust Formations) and Dwyka tillites, both of early Karoo age, dominate. About 20% of rock outcrop is formed by Jurassic intrusive dolerite sheets and dykes. Soils are shallow Glenrosa and Mispah forms, with lime generally present in the entire landscape (Fc land type) and, to a lesser extent, red-yellow apedal, freely drained soils with a high base status and usually <15% clay (Ah and Ai land types) are also found. The salt content in these soils is very high.

Climate Rainfall occurs in late summer and early autumn. MAP ranges from about 100–200 mm. Mean maximum and minimum monthly temperatures in Brandvlei are 39.6°C and –2.2°C for January and July, respectively. Corresponding values for Van Wyksvlei are 39.5°C and –4.6°C. See also climate diagram for NKb 6 Bushmanland Basin Shrubland (Figure 7.2).

Important Taxa Tall Shrubs: *Lycium cinereum* (d), *Rhigozum trichotomum* (d). Low Shrubs: *Aptosimum spinescens* (d), *Hermannia spinosa* (d), *Pentzia spinescens* (d), *Zygophyllum microphyllum* (d), *Aptosimum elongatum*, *A. marlothii*, *Berkheya annectens*, *Eriocephalus microphyllus* var. *pubescens*, *E. pauperrimus*, *E. spinescens*, *Felicia clavipilosa* subsp. *clavipilosa*, *Limeum aethiopicum*, *Osteospermum armatum*, *O. spinescens*, *Pegolettia retrofracta*, *Phaeoptilum spinosum*, *Plinthus karooicus*, *Polygala seminuda*, *Pteronia glauca*, *P. inflexa*, *P. leucoclada*, *P. mucronata*, *P. sordida*, *Rosenia humilis*, *Selago albida*, *Senecio niveus*, *Tetragonia arbuscula*, *Zygophyllum lichtensteinianum*. Succulent Shrubs: *Salsola tuberculata* (d), *Aridaria noctiflora* subsp. *straminea*, *Brownanthus ciliatus* subsp. *ciliatus*, *Galenia sarcophylla*, *Lycium bosciifolium*, *Ruschia intricata*, *Salsola namibica*, *Sarcocaulon patersonii*, *S. salmoniflorum*, *Tripteris sinuata* var. *linearis*, *Zygophyllum flexuosum*. Semiparasitic Shrub: *Thesium hystrix*. Herbs: *Gazania lichtensteinii* (d), *Leysera tenella* (d), *Amaranthus praetermissus*, *Chamaesyce inaequilatera*, *Dicoma capensis*, *Indigastrum argyraeum*, *Lepidium desertorum*, *Monsonia umbellata*, *Radyera urens*, *Sesamum capense*, *Tribulus terrestris*, *T. zeyheri*. Succulent Herbs: *Mesembryanthemum crystallinum*, *M. stenandrum*, *Trianthema parvifolia*, *Zygophyllum simplex*. Graminoids: *Aristida adscensionis* (d), *Enneapogon desvauxii* (d), *Stipagrostis ciliata* (d), *S. obtusa* (d), *Aristida congesta*, *Enneapogon scaber*, *Stipagrostis anomala*, *Tragus berteronianus*, *T. racemosus*.

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Figure 7.7 NKb 6 Bushmanland Basin Shrubland: Dwarf shrublands of the central Bushmanland with *Rhigozum trichotomum* and *Stipagrostis* species (Northern Cape, Brandvlei).

in the south. Altitude varies mostly from 1 000–1 500 m.

Vegetation & Landscape Features Much dissected landscape in the south-west associated with the tributaries of the upper catchment of the Sak River (e.g. Renoster River, Riet River, Klein Sak River), often rocky. Mixture of small-leaved shrubs and shrubby succulents (*Brownanthus*, *Drosanthemum*, *Ruschia* etc.) with drought-resistant (mostly 'white') grasses is the determinant feature of the vegetation structure.

Geology & Soils Karoo sediments (shales, mudstones and arenites) of the Beaufort Group (Adelaide Subgroup) and to a lesser extent also of the Waterford Formation (Ecca Group). Intrusive dolerites of the Jurassic Karoo Dolerite Suite also feature. Glenrosa and Mispah soils (with lime generally present in the entire landscape) are overwhelmingly dominant. Fc land type dominates.

Biogeographically Important Taxon (Bushmanland endemic) Succulent Herb: *Tridentea dwequensis*.

Endemic Taxa Herb: *Cromidon minutum*. Geophytic Herbs: *Ornithogalum bicornutum*, *O. ovatum* subsp. *oliverorum*.

Conservation Least threatened. Target 21%. None of the unit is conserved in statutory conservation areas. No signs of serious transformation, but scattered individuals of *Prosopis* sp. occur in some areas (e.g. in the vicinity of the Sak River drainage system), and some localised dense infestations form closed 'woodlands' along the eastern border of the unit with Northern Upper Karoo (east of Van Wyksvlei). Erosion is moderate (56%) and low (34%).

Remarks The Bushmanland Basin forms an environment for a number of endorheic pans (vloere) and extensive systems of intermittent river channels (including that of the Sak River). In comparison to the bordering Bushmanland Arid Grassland in the north, the vegetation of the Bushmanland Basin shows increased presence of shrubs (especially succulents) and plant indicators of high salt status of soil.

Climate Most of the precipitation occurs in autumn, peaking in March. MAP ranges from about 120–220 mm. Mean maximum and minimum monthly temperatures in Fraserburg are 36.2°C and –5.7°C for January and July, respectively. Corresponding values for Williston are 38.1°C and –4.5°C. Incidence of frost ranges from around 30 frost days per year in the north to about 60 days in the south. See also climate diagram for NKu 1 Western Upper Karoo (Figure 7.2).

Important Taxa Tall Shrubs: *Lycium cinereum* (d), *L. pilifolium*, *Rhigozum trichotomum*, *Tripteris sinuata* var. *linearis*. Low Shrubs: *Chrysocoma ciliata* (d), *Eriocephalus ericoides* subsp. *ericoides* (d), *E. spinescens* (d), *Helichrysum lucilioides* (d), *Osteospermum spinescens* (d), *Pentzia globosa* (d), *P. spinescens* (d), *Tetragonia arbuscula* (d), *Amphiglossa triflora*, *Aptosimum elongatum*, *A. indivisum*, *A. spinescens*, *Asparagus capensis* var. *capensis*, *Berkheya annectens*, *Eriocephalus decussatus*, *E. pauperrimus*, *Euryops imbricatus, E. multifidus*, *Felicia macrorrhiza*, *F. muricata*, *Hermannia cuneifolia*, *H. grandiflora*, *H. multiflora*, *H. spinosa*, *Limeum aethiopicum*, *Melolobium candicans*,

References Acocks (1953, 1988).

Upper Karoo

NKu 1 Western Upper Karoo

VT 29 Arid Karoo and Desert False Grassveld (82%) (Acocks 1953). LR 49 Bushmanland Nama Karoo (84%) (Low & Rebelo 1996).

Distribution Northern Cape Province and a small part in the Western Cape Province: Plains from the Fish River and upper reaches of the Renoster River in the west as far as Fraserburg and Carnarvon in the east, sandwiched between the Bushmanland Basin in the north and the Roggeveld Karoo and edges of the Great Escarpment

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Figure 7.8 NKu 1 Western Upper Karoo: Shrub-rich karoo grasslands dominated by *Aristida* and *Stipagrostis* northeast of Williston (Northern Cape).

Microloma armatum, *Pegolettia retrofracta*, *Pentzia incana*, *P. lanata*, *Plinthus karooicus*, *Polygala pungens*, *Pteronia adenocarpa*, *P. glauca*, *P. mucronata*, *P. sordida*, *Rosenia glandulosa*, *R. humilis*, *Selago albida*, *Stachys cuneata*, *Zygophyllum microphyllum*. Succulent Shrubs: *Ruschia intricata* (d), *Aridaria noctiflora* subsp. *straminea*, *Bassia salsoloides*, *Brownanthus ciliatus* subsp. *ciliatus*, *Drosanthemum ambiguum*, *D. lique*, *Euphorbia rectirama*, *Galenia sarcophylla*, *Salsola calluna*, *S. glabrescens*, *S. rabieana*, *S. tuberculata*, *Sarcocaulon patersonii*, *Zygophyllum flexuosum*. Herbs: *Lepidium africanum* subsp. *africanum*, *L. desertorum*, *Leysera tenella*, *Pelargonium minimum*, *Sutera pinnatifida*, *Ursinia nana*. Succulent Herbs: *Mesembryanthemum crystallinum, Psilocaulon coriarium*. Geophytic Herbs: *Drimia intricata*, *Oxalis depressa*, *Tritonia karooica*. Graminoids: *Aristida congesta* (d), *Enneapogon desvauxii* (d), *Stipagrostis ciliata* (d), *S. obtusa* (d), *Aristida adscensionis*, *A. diffusa*, *Eragrostis bicolor*, *E. obtusa*, *Fingerhuthia africana*, *Tragus berteronianus*, *T. koelerioides*.

Biogeographically Important Taxon (Western distribution limit) Graminoid: *Eragrostis lehmanniana*.

Endemic Taxa Succulent Shrub: *Stomatium villetii*. Herb: *Zaluzianskya bella*.

Conservation Least threatened. Target 21%. None conserved in statutory conservation areas. Very little transformed. Erosion is moderate (52%) and low (44%).

Remarks Even when present in relatively small quantities, species such as *Drosanthemum lique* and *Pteronia sordida* are shown by fistula samples to be consistently grazed by several types of sheep and goats in this vegetation type in all seasons of the year (Du Toit et al. 1995). By contrast, even when common, species such as *Pentzia globosa* appear to be consistently avoided by these animals throughout the year.

References Acocks (1953, 1988), Du Toit (1996).

NKu 2 Upper Karoo Hardeveld

VT 29 Arid Karoo and Desert False Grassveld (23%), VT 27 Central Upper Karoo (15%), VT 26 Karroid Broken Veld (12%), VT 35 False Arid Karoo (12%) (Acocks 1953). LR 50 Upper Nama Karoo (31%), LR 49 Bushmanland Nama Karoo (23%) (Low & Rebelo 1996).

Distribution Northern, Western and Eastern Cape Provinces: Discrete areas of slopes and ridges including dolerite dykes and sills in the region spanning Middelpos in the west and Strydenburg, Richmond and Nieu-Bethesda in the east. Most crest areas and steep slopes of the Great Escarpment facing south between Teekloofpas (connecting Leeu-Gamka and Fraserburg) and eastwards to Graaff-Reinet. Altitude varies mostly from 1 000–1 900 m.

Vegetation & Landscape Features Steep slopes of koppies, butts, mesas and parts of the Great Escarpment covered with large boulders and stones supporting sparse dwarf Karoo scrub with drought-tolerant grasses of genera such as *Aristida, Eragrostis* and *Stipagrostis*.

Geology & Soils Primitive, skeletal soils in rocky areas developing over sedimentary rocks such as mudstones and arenites of the Adelaide Subgroup of the Karoo Supergroup and to a lesser extent also the Ecca Group (Waterford and Volksrust Formations) as well as Jurassic dolerite sills and dykes and subsummit positions of mesas and butts with dolerite boulder slopes. Almost entirely Ib land type.

Climate In the western part of its area this unit experiences the same climate as the Western Upper Karoo. In the eastern part the climate is very close to that of Karoo Escarpment. The MAP ranges from about 150 mm in the northwest to 350 mm along some grassland margins on the Great Escarpment and in the east. Water concentrates between rocks as a result of rainfall runoff. Incidence of frost is relatively high, but ranging widely from <30 days per year at lower altitudes to >80 days at highest altitudes. See also climate diagram for NKu 2 Upper Karoo Hardeveld (Figure 7.2).

Important Taxa Tall Shrubs: *Lycium cinereum* (d), *Rhigozum obovatum* (d), *Cadaba aphylla*, *Diospyros austro-africana*, *Ehretia rigida* subsp. *rigida*, *Lycium oxycarpum*, *Melianthus comosus*, *Rhus burchellii*. Low Shrubs: *Chrysocoma ciliata* (d), *Eriocephalus ericoides* subsp. *ericoides* (d), *Euryops lateriflorus* (d), *Felicia muricata* (d), *Limeum aethiopicum* (d), *Pteronia glauca* (d), *Amphiglossa triflora*, *Aptosimum elongatum*, *A. spinescens*, *Asparagus mucronatus*, *A. retrofractus*, *A. striatus*, *A. suaveolens*, *Eriocephalus spinescens*, *Euryops annae*, *E. candollei, E. empetrifolium, E. nodosus, Felicia filifolia* subsp. *filifolia*, *Garuleum latifolium*, *Helichrysum lucilioides*, *H. zeyheri*, *Hermannia filifolia* var. *filifolia*, *H. multiflora*, *H. pulchella*, *H. vestita*, *Indigofera sessilifolia*, *Jamesbrittenia atropurpurea*, *Lessertia frutescens*, *Melolobium candicans*, *M. microphyllum*, *Microloma armatum*, *Monechma incanum*, *Nenax microphylla*, *Pegolettia retrofracta*, *Pelargonium abrotanifolium*, *P. ramosissimum*, *Pentzia globosa*, *P. spinescens*, *Plinthus karooicus*, *Polygala seminuda*, *Pteronia adenocarpa*, *P. sordida*, *Rosenia humilis*, *Selago albida*, *Solanum capense*, *Sutera halimifolia*, *Tetragonia arbuscula*, *Wahlenbergia tenella*. Succulent Shrubs: *Aloe broomii*, *Drosanthemum lique*, *Faucaria bosscheana*, *Kleinia longiflora*, *Pachypodium succulentum*, *Trichodiadema barbatum*, *Zygophyllum flexuosum*. Semiparasitic Shrub: *Thesium lineatum* (d). Herbs: *Troglophyton capillaceum* subsp. *capillaceum*, *Dianthus caespitosus* subsp. *caespitosus*, *Gazania krebsiana*, *Lepidium africanum* subsp. *africanum*, *Leysera tenella*, *Pelargonium minimum*, *Sutera pinnatifida*, *Tribulus terrestris*. Geophytic Herbs: *Albuca setosa*, *Androcymbium albomarginatum*, *Asplenium cordatum*, *Boophone disticha*, *Cheilanthes bergiana*, *Drimia intricata*, *Oxalis depressa*, Graminoids: *Aristida adscensionis* (d), *A. congesta* (d), *A. diffusa* (d), *Cenchrus ciliaris* (d), *Enneapogon desvauxii* (d), *Eragrostis lehmanniana* (d), *E. obtusa* (d), *Sporobolus fimbriatus* (d), *Stipagrostis obtusa* (d), *Cynodon incompletus*, *Digitaria eriantha*, *Ehrharta calycina*, *Enneapogon scaber*, *E. scoparius*, *Eragrostis curvula*, *E. nindensis, E. procumbens*, *Fingerhuthia africana*, *Heteropogon contortus*, *Merxmuellera disticha*, *Stipagrostis ciliata*, *Themeda triandra*, *Tragus berteronianus*, *T. koelerioides*.

Endemic Taxa Succulent Shrubs: *Aloe chlorantha*, *Crassula barbata* subsp. *broomii*, *Delosperma robustum, Sceletium expansum*, *Stomatium suaveolens*. Low Shrubs: *Cineraria polycephala*, *Euryops petraeus*, *Lotononis azureoides*, *Selago magnakarooica*. Tall Shrub: *Anisodontea malvastroides*. Herbs: *Cineraria arctotidea*, *Vellereophyton niveum*. Succulent Herbs: *Adromischus fallax*, *A. humilis*. Geophytic Herbs: *Gethyllis longistyla*, *Lachenalia auriolae, Ornithogalum paucifolium* subsp. *karooparkense*.

Conservation Least threatened. Target 21%. Only about 3% statutorily conserved in Karoo National Park and Karoo Nature Reserve. Small percentage also protected in private reserves such as Rupert Game Farm. Erosion is moderate (64%) and high (2%).

Remarks One of the richer floras of the Nama-Karoo Biome, this type also contains a substantial number of diagnostic species relative to the surrounding extensive flats (i.e. the Eastern, Northern and Western Upper Karoo vegetation units). Examples are the widespread occurrence of *Asparagus mucronatus, A. striatus*, *Cissampelos capensis*, *Pachypodium succulentum*,

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Figure 7.9 NKu 2 Upper Karoo Hardeveld: Dolerite koppies supporting grassy karoo shrublands south of Loxton (Northern Cape).

Rhigozum obovatum and *Cenchrus ciliaris* in this unit. Many of the endemic species listed are found along the Great Escarpment part of this vegetation type.

Reference Palmer (1990).

NKu 3 Northern Upper Karoo

VT 35 False Arid Karoo (35%), VT 36 False Upper Karoo (27%) (Acocks 1953). LR 50 Upper Nama Karoo (44%), LR 52 Eastern Mixed Nama Karoo (24%) (Low & Rebelo 1996).

Distribution Northern Cape and Free State Provinces: Northern regions of the Upper Karoo plateau from Prieska, Vosburg and Carnarvon in the west to Philipstown, Petrusville and Petrusburg in the east. Bordered in the north by Niekerkshoop, Douglas and Petrusburg and in the south by Carnarvon, Pampoenpoort and De Aar. A few patches occur in Griqualand West. Altitude varies mostly from 1 000–1 500 m.

Vegetation & Landscape Features Shrubland dominated by dwarf karoo shrubs, grasses and *Acacia mellifera* subsp. *detinens* and some other low trees (especially on sandy soils in the northern parts and vicinity of the Orange River). Flat to gently sloping, with isolated hills of Upper Karoo Hardeveld in the south and Vaalbos Rocky Shrubland in the northeast and with many interspersed pans.

Geology & Soils Shales of the Volksrust Formation and to a lesser extent the Prince Albert Formation (both of the Ecca Group) as well as Dwyka Group diamictites form the underlying geology. Jurassic Karoo Dolerite sills and sheets support this vegetation complex in places. Wide stretches of land are covered by superficial deposits including calcretes of the Kalahari Group. Soils are variable from shallow to deep, red-yellow, apedal, freely drained soils to very shallow Glenrosa and Mispah forms. Mainly Ae, Ag and Fc land types.

Climate Rainfall peaks in autumn (March). MAP ranges from about 190 mm in the west to 400 mm in the northeast. Mean maximum and minimum monthly temperatures for Britstown are 37.9°C and –3.6°C for January and July, respectively. Corresponding values are 37.1°C and –4.8°C for De Aar and 39.0°C and –2.3°C for Kareekloof (northwest of Strydenburg). See also climate diagram for NKu 3 Northern Upper Karoo (Figure 7.2).

Important Taxa Small Trees: *Acacia mellifera* subsp. *detinens*, *Boscia albitrunca*. Tall Shrubs: *Lycium cinereum* (d), *L. horridum*, *L. oxycarpum*, *L. schizocalyx*, *Rhigozum trichotomum*. Low Shrubs: *Chrysocoma ciliata* (d), *Gnidia polycephala* (d), *Pentzia calcarea* (d), *P. globosa* (d), *P. incana* (d), *P. spinescens* (d), *Rosenia humilis* (d), *Amphiglossa triflora*, *Aptosimum marlothii*, *A. spinescens*, *Asparagus glaucus*, *Barleria rigida*, *Berkheya annectens*, *Eriocephalus ericoides* subsp. *ericoides*, *E. glandulosus*, *E. spinescens*, *Euryops asparagoides*. *Felicia muricata*, *Helichrysum lucilioides*, *Hermannia spinosa*, *Leucas capensis*, *Limeum aethiopicum*, *Melolobium candicans*, *Microloma armatum*, *Osteospermum leptolobum*, *O. spinescens*, *Pegolettia retrofracta*, *Pentzia lanata*, *Phyllanthus maderaspatensis*, *Plinthus karooicus*, *Pteronia glauca*, *P. sordida*, *Selago geniculata*, *S. saxatilis*, *Tetragonia arbuscula*, *Zygophyllum lichtensteinianum*. Succulent Shrubs: *Hertia pallens*, *Salsola calluna*, *S. glabrescens*, *S. rabieana*, *S. tuberculata*, *Zygophyllum flexuosum*. Semiparasitic Shrub: *Thesium hystrix* (d), Herbs: *Chamaesyce inaequilatera*, *Convolvulus sagittatus*, *Dicoma capensis*, *Gazania krebsiana*, *Hermannia comosa*, *Indigofera alternans*, *Lessertia pauciflora*, *Radyera urens*, *Sesamum capense*, *Sutera pinnatifida*, *Tribulus terrestris*, *Vahlia capensis*. Succulent Herb: *Psilocaulon coriarium*. Geophytic Herb: *Moraea pallida*.Graminoids: *Aristida adscensionis* (d), *A. congesta* (d), *A. diffusa* (d), *Enneapogon desvauxii* (d), *Eragrostis lehmanniana* (d), *E. obtusa* (d), *E. truncata* (d), *Sporobolus fimbriatus* (d), *Stipagrostis obtusa* (d), *Eragrostis bicolor*, *E. porosa*, *Fingerhuthia africana*, *Heteropogon contortus*, *Stipagrostis ciliata*, *Themeda triandra*, *Tragus berteronianus*, *T. koelerioides*, *T. racemosus*.

Biogeographically Important Taxa Herb (western distribution limit): *Convolvulus boedeckerianus*. Tall Shrub (southern limit of distribution): *Gymnosporia szyszylowiczii* subsp. *namibiensis*.

Endemic Taxa Succulent Shrubs: *Lithops hookeri*, *Stomatium pluridens*. Low Shrubs: *Atriplex spongiosa*, *Galenia exigua*. Herb: *Manulea deserticola*.

Conservation Least threatened. Target 21%. None conserved in statutory conservation areas. About 4% has been cleared for cultivation (the highest proportion of any type in the Nama-Karoo) or irreversibly transformed by building of dams (Houwater, Kalkfontein and Smart Syndicate Dams). Areas of human settlements are increasing in the northeastern part of this vegetation type (Hoffman et al. 1999). Erosion is moderate (46.2%), very low (32%) and low (20%). *Prosopis glandulosa*, regarded as one of the 12 agriculturally most important invasive alien plants in South Africa, is widely distributed in this vegetation type (Hoffman et al. 1999). *Prosopis* occurs in generally isolated patches, with densities ranging from very scattered to medium (associated with the lower Vaal River drainage system and the confluence with the Orange River) to localised closed woodland on the western border of the unit with Bushmanland Basin Shrubland.

Remark This Karoo unit is found on floristic and ecological gradients between the Nama-Karoo, arid Kalahari savanna and arid highveld grasslands.

References Acocks (1953, 1988), Werger (1980), Palmer (1990).

NKu 4 Eastern Upper Karoo

VT 36 False Upper Karoo (54%) (Acocks 1953). LR 52 Eastern Mixed Nama Karoo (61%) (Low & Rebelo 1996).

Distribution Northern Cape, Eastern Cape and Western Cape Provinces: Between Carnarvon and Loxton in the west, De Aar, Petrusville and Venterstad in the north, Burgersdorp, Hofmeyr and Cradock in the east and the Great Escarpment and the Sneeuberge-Coetzeesberge mountain chain in the south. Altitude varies between mostly 1 000–1 700 m.

Vegetation & Landscape Features Flats and gently sloping plains (interspersed with hills and rocky areas of Upper Karoo Hardeveld in the west, Besemkaree Koppies Shrubland in the northeast and Tarkastad Montane Shrubland in the southeast), dominated by dwarf microphyllous shrubs, with 'white' grasses of the genera *Aristida* and *Eragrostis* (these become prominent especially in the early autumn months after good summer rains). The grass cover increases along a gradient from southwest to northeast.

Geology & Soils Mudstones and sandstones of the Beaufort Group (incl. both Adelaide and Tarkastad Subgroups) supporting duplex soils with prismacutanic and/or pedocutanic diagnostic horizons dominant (Da land type) as well as some shallow Glenrosa and Mispah soils (Fb and Fc land types). In places, less prominent Jurassic dolerites (Karoo Dolerite Suite) are also found.

Climate Rainfall mainly in autumn and summer, peaking in March. MAP ranges from about 180 mm in the west to 430 mm in the east. Incidence of frost is relatively high, but ranging widely from <30 days (in the lower-altitude Cradock area) to >80 days of frost per year (bordering the Upper Karoo Hardeveld on the Compassberg and mountains immediately to the west). Mean maximum and minimum monthly temperatures in Middelburg (Grootfontein) are 36.1°C and –7.2°C for January and July, respectively. Corresponding values are 37°C and –8°C for Victoria West and 36.6°C and –4.2°C for Hofmeyr. See also climate diagram for NKu 4 Eastern Upper Karoo.

Important Taxa Tall Shrubs: *Lycium cinereum* (d), *L. horridum*, *L. oxycarpum*. Low Shrubs: *Chrysocoma ciliata* (d), *Eriocephalus ericoides* subsp. *ericoides* (d), *E. spinescens* (d), *Pentzia globosa* (d), *P. incana* (d), *Phymaspermum parvifolium* (d), *Salsola calluna* (d), *Aptosimum procumbens*, *Felicia muricata*, *Gnidia polycephala*, *Helichrysum dregeanum*, *H. lucilioides*, *Limeum aethiopicum*, *Nenax microphylla*, *Osteospermum leptolobum*, *Plinthus karooicus*, *Pteronia glauca*, *Rosenia humilis*, *Selago geniculata*, *S. saxatilis*. Succulent Shrubs: *Euphorbia hypogaea*, *Ruschia intricata*. Herbs: *Indigofera alternans*, *Pelargonium minimum*, *Tribulus terrestris*. Geophytic Herbs: *Moraea pallida* (d), *Moraea polystachya*, *Syringodea bifucata*, *S. concolor*. Succulent Herbs: *Psilocaulon coriarium*, *Tridentea jucunda*, *T. virescens*. Graminoids: *Aristida congesta* (d), *A. diffusa* (d), *Cynodon incompletus* (d), *Eragrostis bergiana* (d), *E. bicolor* (d), *E. lehmanniana* (d), *E. obtusa* (d), *Sporobolus fimbriatus* (d), *Stipagrostis ciliata* (d), *Tragus koelerioides* (d), *Aristida adscensionis*, *Chloris virgata*, *Cyperus usitatus*, *Digitaria eriantha*, *Enneapogon desvauxii*, *E. scoparius*, *Eragrostis curvula*, *Fingerhuthia africana*, *Heteropogon contortus*, *Sporobolus ludwigii*, *S. tenellus*, *Stipagrostis obtusa*, *Themeda triandra*, *Tragus berteronianus*.

Endemic Taxa Succulent Shrubs: *Chasmatophyllum rouxii*, *Hertia cluytiifolia*, *Rabiea albinota*, *Salsola tetrandra*. Tall Shrub: *Phymaspermum scoparium*. Low Shrubs: *Aspalathus acicularis* subsp. *planifolia*, *Selago persimilis*, *S. walpersii*.

Conservation Least threatened. Target 21%. Statutorily conserved in Mountain Zebra and Karoo National Parks as well as in Oviston, Commando Drift, Rolfontein and Gariep Dam Nature Reserves. About 2% of the unit has been transformed, largely due to building of dams (Gariep, Grassridge, Killowen, Kommandodrift, Kriegerspoort, Lake Arthur, Modderpoort, Schuil Hoek, Vanderkloof, Victoria West, Wonderboom and Zoetvlei). *Medicago laciniata* is a common and widespread alien plant. Erosion is moderate (60%) and high (38%). Veld managers perceive much of the Eastern Upper Karoo to be experiencing changes in species composition requiring high-priority action (Hoffman et al. 1999).

Remarks This vegetation type has the largest mapped area of all vegetation units. The regions between Colesberg (Northern Cape) and Springfontein (Free State) fall within a broad ecotone where grassy Eastern Upper Karoo grades into Xhariep Karroid Grassland.

References Acocks (1953, 1988), Werger (1973, 1980), Van der Walt (1980), Palmer (1988, 1991a, b, c), Jooste (1989), Lloyd & Badenhorst (1995, 1996), Du Toit (1996), Low & Rebelo (1996, 1998), Hoffman et al. (1999), Pienaar et al. (2004), Brown & Bezuidenhout (2005).

L. Mucina

Figure 7.10 NKu 4 Eastern Upper Karoo: Typical winter view of karoo shrublands with species of *Pentzia*, *Eriocephalus*, *Rosenia* and *Lycium* and scattered 'white grasses' (species of *Aristida*, *Eragrostis*, *Stipagrostis*) south of Richmond (Northern Cape).

Lower Karoo

NKl 1 Gamka Karoo

VT 26 Karroid Broken Veld (76%) (Acocks 1953). LR 53 Great Nama Karoo (70%) (Low & Rebelo 1996). BHU 91 Gamka Broken Veld (Cowling & Heijnis 2001).

Distribution Western Cape and Eastern Cape Provinces and marginally into the Northern Cape Province: Large basin between the Great Escarpment (Nuweveld Mountains) in the north and northwest and Cape Fold Belt Mountains (mostly Swartberg Mountains) in the south. From approximately the edge of

L. Mucina

Figure 7.11 NKl 1 Gamka Karoo: Dry karoo shrublands in the surrounds of the Gamka River at the foot of the Swartberg Mountains in the background near Leeuw-Gamka (Western Cape).

the Gamka basin catchment area (i.e. of the Dwyka River tributary) in the west to about the Kariega River in the east. Altitude varies mostly from 500–1 100 m.

Vegetation & Landscape Features Extremely irregular to slightly undulating plains covered with dwarf spiny shrubland dominated by Karoo dwarf shrubs (e.g. *Chrysocoma ciliata, Eriocephalus ericoides*) with rare low trees (e.g. *Euclea undulata*). Dense stands of drought-resistant grasses (*Stipagrostis, Aristida*) cover (especially after abundant rains) broad sandy bottomlands.

Geology & Soils Mudstones and sandstones of the Beaufort Group (Adelaide Subgroup) with some Ecca (Fort Brown Formation) shales supporting very shallow and stony soils of the Glenrosa and/or Mispah forms, typical of Fc land type.

Climate One of the most arid units of the Nama-Karoo Biome. Rainfall mainly in autumn and summer, with a marked peak in March and low levels of cyclonic rain in winter. This region is in the rainshadow of Cape Fold Belt mountains in the south, MAP ranging from about 100 mm in some areas between the Dwyka and Gamka Rivers to about 240 mm against the Great Escarpment. Mean maximum and minimum monthly temperatures in Beaufort West are 38.7°C and –3.2°C for January and July, respectively. Strong northwesterly winds occur in winter. See also climate diagram for NKl 1 Gamka Karoo (Figure 7.2).

Important Taxa Tall Shrubs: *Lycium cinereum* (d), *L. oxycarpum* (d), *Rhigozum obovatum* (d), *Acacia karroo*, *Cadaba aphylla*, *Lycium schizocalyx*, *Rhus burchellii*, *Sisyndite spartea*. Low Shrubs: *Chrysocoma ciliata* (d), *Eriocephalus ericoides* subsp. *ericoides* (d), *E. spinescens* (d), *Felicia muricata* (d), *Galenia fruticosa* (d), *Limeum aethiopicum* (d), *Pentzia incana* (d), *Pteronia adenocarpa* (d), *Rosenia humilis* (d), *Aptosimum indivisum*, *Asparagus burchellii*, *Blepharis mitrata*, *Eriocephalus microphyllus* var. *pubescens*, *Felicia filifolia* subsp. *filifolia*, *F. muricata* subsp. *cinerascens*, *Galenia secunda*, *Garuleum bipinnatum*, *G. latifolium*, *Gomphocarpus filiformis*, *Helichrysum lucilioides*, *Hermannia desertorum*, *H. grandiflora*, *H. spinosa*, *Melolobium candicans*, *Microloma armatum*, *Monechma spartioides*, *Pentzia pinnatisecta*, *Plinthus karooicus*, *Polygala seminuda*, *Pteronia glauca*, *P. sordida*, *P. viscosa*, *Selago geniculata*, *Sericocoma avolans*, *Zygophyllum microcarpum*, *Z. microphyllum*. Succulent Shrubs: *Ruschia intricata* (d), *Aridaria noctiflora* subsp. *straminea*, *Crassula muscosa*, *Drosanthemum lique*, *Galenia sarcophylla*, *Kleinia longiflora*, *Ruschia spinosa*, *Salsola tuberculata*, *Sarcocaulon patersonii*, *Trichodiadema barbatum*, *Tripteris sinuata* var. *linearis*. Semiparasitic Shrub: *Thesium lineatum*. Herbs: *Gazania lichtensteinii* (d), *Chamaesyce inaequilatera*, *Dicoma capensis*, *Galenia glandulifera*, *Lepidium africanum* subsp. *africanum*, *L. desertorum*, *Lessertia pauciflora* var. *pauciflora*, *Leysera tenella*, *Osteospermum microphyllum*, *Sesamum capense*, *Tetragonia microptera*, *Tribulus terrestris*, *Ursinia nana*. Geophytic Herbs: *Drimia intricata*, *Moraea polystachya*. Graminoids: *Aristida congesta* (d), *A. diffusa* (d), *Fingerhuthia africana* (d), *Stipagrostis ciliata* (d), *S. obtusa* (d), *Aristida adscensionis*, *Cenchrus ciliaris*, *Digitaria argyrograpta*, *Enneapogon desvauxii*, *Enneapogon scaber*, *Eragrostis homomalla*, *E. lehmanniana*, *E. obtusa*, *Tragus berteronianus*, *T. koelerioides*.

Biogeographically Important Taxa (*Endemic to Great Karoo Basin) Succulent Shrubs: *Hereroa latipetala** (also found in Prince Albert Succulent Karoo), *H. odorata** (also found in Koedoesberge-Moordenaars Karoo), *Pleiospilos compactus* (southern and western limits of distribution), *Rhinephyllum luteum**, *Stapelia engleriana**. Geophytic Herb: *Tritonia tugwelliae**. Low Shrub: *Felicia lasiocarpa**. Succulent Herbs: *Piaranthus comptus**, *Tridentea parvipuncta* subsp. *parvipuncta**. Graminoid: *Oropetium capense* (westernmost limit of distribution).

Endemic Taxa Succulent Shrubs: *Chasmatophyllum stanleyi*, *Hereroa incurva*, *Hoodia dregei, Ruschia beaufortensis*. Low Shrubs: *Jamesbrittenia tenuifolia*. Herb: *Manulea karrooica*. Succulent Herb: *Piaranthus comptus*.

Conservation Least threatened. Target 16%. About 2% statutorily conserved in the Karoo National Park and some in private reserves, such as Steenbokkie Private Nature Reserve (near Beaufort West). Only small part has undergone transformation. The alien *Salsola kali* is a serious infestation problem locally. Erosion is moderate (78%), low (11%) and high (11%).

References Acocks (1953, 1979, 1988), Du Toit (1996), Low & Rebelo (1996, 1998), Rubin & Palmer (1996), Cowling & Heijnis (2001).

NKl 2 Eastern Lower Karoo

VT 30 Central Lower Karoo (43%), VT 26 Karroid Broken Veld (31%) (Acocks 1953). LR 54 Central Lower Nama Karoo (94%) (Low & Rebelo 1996). Grassy Dwarf Shrublands of the Camdebo and Aberdeen plains, Dwarf Shrublands (typicum) of the Camdebo & Succulent Dwarf Shrubland (Palmer 1991a).

Distribution Eastern Cape and Western Cape Provinces: Plains east of the Kariega and Buffels Rivers in the area south of the Camdebo Mountains and the line of mountains linking to the Coetzeesberge encompassing Aberdeen, Graaff-Reinet and Pearston (region called Camdebo) and plains south of Aberdeen to Klipplaat and Miller. Contains some higher elevation islands of Camdebo Escarpment Thicket, Groot Thicket and Lower Karoo Gwarrieveld. Altitude varies mostly from 500–1 100 m.

Vegetation & Landscape Features Plains interrupted by some dolerite dykes, butts and mesas. The dominating vegetation is low to middle-height microphyllous shrubland with

drought-resistant 'white' grasses becoming abundant in places, especially on sandy and silty bottomlands. Leaf-succulent dwarf shrubs of the families Aizoaceae and Crassulaceae can also be encountered.

Geology & Soils Flat or gently sloping pediments composed of mudstone and resistant sandstones of the Beaufort Group (Adelaide Subgroup), Ecca sediments and Dwyka tillites in the south, with some Jurassic dolerite intrusions in the north. About half the area has red-yellow, apedal, freely drained soils, <300 mm deep, with a high base status (Ag land type). Also shallow Glenrosa and/or Mispah soils (Fc land type).

Climate Rainfall mostly in late summer and early autumn, with main peak in March. MAP ranges from about 150 mm in the west to 350 mm in the east. Mean maximum and minimum monthly temperatures for Graaff-Reinet are 38.6°C and –0.3°C for January and July, respectively. See also climate diagram for NKl 2 Eastern Lower Karoo (Figure 7.2).

Important Taxa Small Trees: *Acacia karroo*. Tall Shrubs: *Lycium cinereum* (d), *L. oxycarpum* (d), *Cadaba aphylla*, *Carissa haematocarpa*, *Grewia robusta*, *Lycium schizocalyx*, *Rhigozum obovatum*. Low Shrubs: *Eriocephalus ericoides* subsp. *ericoides* (d), *Felicia muricata* (d), *Pentzia incana* (d), *Rosenia humilis* (d), *Aptosimum elongatum*, *Asparagus striatus*, *A. suaveolens*, *Barleria pungens*, *Blepharis capensis*, *B. mitrata*, *Chrysocoma ciliata*, *Euryops anthemoides*, *Felicia muricata*, *Galenia secunda*, *Garuleum latifolium*, *Helichrysum zeyheri*, *Hermannia cuneifolia*, *Indigofera sessilifolia*, *Limeum aethiopicum*, *Microloma armatum*, *Pegolettia retrofracta*, *Phymaspermum parvifolium*, *Plinthus karooicus*, *Polygala seminuda*, *Pteronia adenocarpa*, *P. glauca*, *P. sordida*, *Selago fruticosa*, *Senecio acutifolius*, *Sutera halimifolia*, *Zygophyllum microphyllum*. Succulent Shrubs: *Ruschia cradockensis* subsp. *cradockensis* (d), *Astroloba foliolosa*, *Crassula corallina*, *Drosanthemum lique*, *D. subspinosum*, *Euphorbia ferox*, *Mestoklema tuberosum*, *Pachypodium succulentum*, *Rhombophyllum nelii*, *Sarcocaulon camdeboense*, *S. patersonii*, *Trichodiadema barbatum*. Semiparasitic Shrub: *Thesium hystrix*, Graminoids: *Aristida adscensionis* (d), *A. congesta* (d), *Eragrostis lehmanniana* (d), *E. obtusa* (d), *Tragus berteronianus* (d), *T. koelerioides* (d), *T. racemosus* (d), *A. diffusa*, *Chloris virgata*, *Cynodon incompletus*, *Enneapogon desvauxii*, *Eragrostis curvula*, *Stipagrostis obtusa*. Herbs: *Chamaesyce inaequilatera*, *Convolvulus sagittatus*, *Gazania krebsiana*, *Lepidium africanum* subsp. *africanum*, *Tribulus terrestris*. Succulent Herbs: *Crassula muscosa*, *Psilocaulon articulatum*, *P. coriarium*, *Senecio radicans*. Geophytic Herbs: *Albuca setosa*, *Drimia anomala*, *D. intricata*, *Moraea polystachya*.

Endemic Taxa Succulent Shrubs: *Aloinopsis rubrolineata*, *Chasmatophyllum nelii*, *Cylindrophyllum calamiforme*, *Euphorbia coerulans*, *Ruschia vanderbergiae*. Succulent Herbs: *Haworthia decipiens* var. *cyanea*, *H. greenii*.

Conservation Least threatened. Target 16%. Some of patches statutorily conserved in Aberdeen and Karoo Nature Reserves as well as in private reserves such as Minnawill Game Farm. Between 1% and 2% transformed by alien infestation. Erosion is high (45%) and moderate (45%).

Remarks Vegetation structure of the Eastern Lower Karoo differs from the Gamka Karoo with its higher proportion of succulent dwarf shrubs (species of *Ruschia*) and higher frequency of larger woody shrubs (*Diospyros, Euclea, Lycium, Rhus*) associated with rocky outcrops and other mesic patches.

References Acocks (1953, 1988), Palmer (1988, 1989, 1991a, c), Hoffman (1989a, b), Du Toit (1996).

NKl 3 Lower Karoo Gwarrieveld

VT 26 Karroid Broken Veld (56%) (Acocks 1953). LR 54 Central Lower Nama Karoo (63%) (Low & Rebelo 1996). STEP Sundays Gwarrieveld (61%) (Vlok & Euston-Brown 2002).

Distribution Eastern Cape Province: An irregular northeastern belt south of the Camdebo plains extends westwards along the northern edge of the usually higher-altitude thicket from Westondale (Pearston District), crossing the Sundays River in the Meerlust area (north of Jansenville) to Oatlands. To the west, it flanks the thicket on the Tierberg (Aberdeen District) and its associated ridges. Further south, a belt in the Baroe-Wolwefontein Valley encircles an area of lower-altitude Eastern Lower Karoo and also extends through Seekoeinek to the south. Altitude varies mostly from 500–1 000 m.

Vegetation & Landscape Features Hills and gentle slopes supporting shrubland with sparse canopy of *Euclea undulata, Schotia afra, Boscia oleoides* and *Pappea capensis*. Common shrubs include *Rhigozum obovatum* and *Eriocephalus ericoides*. Very little remains of the palatable grass component, while less palatable species, for example *Aristida diffusa*, are abundant in rocky outcrops. Isolated remnants of *Portulacaria afra* occur in places.

Geology & Soils Predominantly shallow soils of Glenrosa and/or Mispah forms over mostly mudstones and sandstones of the Beaufort Group (Adelaide Subgroup) and some sedimentary rocks of the Ecca Group. Fc land type dominates, Ag land type plays a subordinate role.

Climate Most rainfall in summer and autumn (peaking in March). MAP ranges from about 190–330 mm. See also climate diagram for NKl 3 Lower Karoo Gwarrieveld (Figure 7.2).

Important Taxa Succulent Tree: *Aloe ferox*. Small Trees: *Acacia karroo* (d), *Euclea undulata* (d), *Pappea capensis* (d), *Boscia oleoides*, *Schotia afra* var. *afra*. Tall Shrubs: *Lycium oxycarpum* (d), *Rhigozum obovatum* (d), *Cadaba aphylla*, *Carissa haematocarpa*, *Ehretia rigida* subsp. *rigida*, *Grewia robusta*, *Nymania capensis*, *Rhus longispina*. Woody Climbers: *Cissampelos capensis*, *Rhoicissus digitata*. Epiphytic Semiparasitic Shrub: *Viscum rotundifolium*. Low Shrubs: *Asparagus racemosus* (d), *A. striatus* (d), *Eriocephalus ericoides* subsp. *ericoides* (d), *Euryops anthemoides* (d), *Felicia muricata* (d), *Helichrysum dregeanum* (d), *Limeum aethiopicum* (d), *Pentzia incana* (d), *Aptosimum elongatum*, *Asparagus mucronatus*, *A. suaveolens*, *Barleria pungens*, *Blepharis capensis*, *Chrysocoma ciliata*, *Felicia muricata*, *F. ovata*, *Garuleum latifolium*, *Indigofera obcordata*, *Lantana rugosa*, *Phymaspermum parvifolium*, *Polygala seminuda*, *Rosenia humilis*, *Selago fruticosa*. Succulent Shrubs: *Euphorbia ferox* (d), *Aloe striata* subsp. *karasbergensis*, *Crassula muscosa*, *Drosanthemum lique*, *Euphorbia enopla* var. *viridis*. *E. esculenta*, *E. horrida* var. *noorsveldensis*, *E. mauritanica* var. *corallothamnus*, *Mestoklema tuberosum*, *Pachypodium succulentum*, *Portulacaria afra*, *Trichodiadema barbatum*. Herbs: *Aizoon glinoides*, *Chamaesyce inaequilatera*, *Hermannia pulverata*, *Lepidium africanum* subsp. *africanum*, *Tribulus terrestris*. Geophytic Herbs: *Drimia intricata, Sansevieria hyacinthoides*. Graminoids: *Aristida congesta* (d), *A. diffusa* (d), *Eragrostis lehmanniana* (d), *E. obtusa* (d), *Aristida adscensionis*, *Cynodon incompletus*, *Cyperus capensis*, *Enneapogon desvauxii*, *E. scoparius*, *Eragrostis curvula*, *Panicum maximum*, *Setaria verticillata*, *Sporobolus fimbriatus*, *Tragus koelerioides*.

Endemic Taxon Succulent Herb: *Haworthia bruynsii*.

Conservation Least threatened. Target 16%. None conserved in statutory conservation areas, but small patches protected in

private reserves such as Blaawbosch Game Farm. About 1% transformed by alien infestation (e.g. *Salsola kali*). Erosion is moderate (81%) and very low (10%).

Remarks This vegetation typically occurs sandwiched between Eastern Lower Karoo at lower altitudes and thicket types at higher altitudes. The western and southern sections are rich in succulents, whereas leaf succulents are uncommon in the north-eastern section. *Salsola kali* can be common in some areas.

References Vlok & Euston-Brown (2002), Vlok et al. (2003).

NKl 4 Albany Broken Veld

VT 37 False Karroid Broken Veld (62%) (Acocks 1953). LR 52 Eastern Mixed Nama Karoo (76%) (Low & Rebelo 1996). STEP Saltaire Karroid Thicket (54%) (Vlok & Euston-Brown 2002).

Distribution Eastern Cape Province: Immediately to the north of the Zuurberg Mountains and south of Middlewater, Ripon and the area around the confluence of the Great and Little Fish Rivers and extending eastwards, north of the mountain ridges around Riebeeck East to the Carlisle Bridge area and south of these ridges in the upper Bushmans River Valley past Alicedale and up the New Years River Valley. Including also some irregular linear patches east of Riebeeck East. Altitude varies mostly from 300–800 m.

Vegetation & Landscape Features Low mountain ridges and hills with an open grassy karroid dwarf shrubland with scattered low trees (*Boscia oleoides*, *Euclea undulata, Pappea capensis*, *Schotia afra* var. *afra*) with a matrix of dwarf shrubs (*Becium burchellianum*, *Chrysocoma ciliata*) and grasses (*Eragrostis obtusa*).

Geology & Soils Mainly shales and some sandstones of various stratigraphic units within the Witteberg Group of the Cape Supergroup and the Beaufort, Ecca and Dwyka Groups of the Karoo Supergroup. Mainly Glenrosa and/or Mispah soils (Fc land type) with some red-yellow, apedal, drained soils, with a high base status, generally <300 mm deep, typical of Ag land type.

Climate Bimodal rainfall with main peak in March and secondary peak in November. Some rain falls in the winter months. Rainfall relatively high for the Nama-Karoo. Incidence of frost is low, with less than a tenth of the area experiencing more than 10 frost days per year. MAP ranges from about 290 mm in the west (in the rainshadow of the Zuurberg) to about 500 mm in the east. See also climate diagram for NKl 4 Albany Broken Veld (Figure 7.2).

Important Taxa Succulent Tree: *Aloe ferox*. Small Trees: *Acacia natalitia* (d), *Euclea undulata* (d), *Pappea capensis* (d), *Schotia afra* var. *afra* (d), *Boscia oleoides*, *Cussonia spicata*. Tall Shrubs: *Grewia robusta*, *Lycium cinereum*, *Putterlickia pyracantha*, *Rhigozum obovatum*, *Rhus incisa* var. *effusa*. Low Shrubs: *Asparagus striatus* (d), *A. suaveolens* (d), *Becium burchellianum* (d), *Chrysocoma ciliata* (d), *Selago fruticosa* (d), *Asparagus acocksii*, *A. racemosus*, *Eriocephalus ericoides* subsp. *ericoides*, *Felicia filifolia*, *F. muricata*, *Gnidia cuneata*, *Helichrysum dregeanum*, *Hermannia linearifolia*, *Indigofera sessilifolia*, *Limeum aethiopicum*, *Nenax microphylla*, *Pentzia incana*, *Polygala seminuda*, *Rosenia humilis*. Succulent Shrubs: *Cotyledon campanulata*, *Drosanthemum lique*, *Euphorbia meloformis*, *E. rectirama*, *Faucaria britteniae*, *F. tigrina, Mestoklema tuberosum*. Herbs: *Gazania krebsiana*, *Hermannia pulverata*, *Hibiscus pusillus*. Geophytic Herbs: *Bulbine frutescens*, *Drimia anomala*, *Eriospermum dregei*, *Ornithogalum dyeri*. Succulent Herbs: *Gasteria bicolor*, *Ophionella arcuata* subsp. *arctuata, Platythyra hackeliana*, *Senecio radicans, Stapeliopsis pillansii*. Graminoids: *Aristida congesta* (d), *Eragrostis obtusa* (d), *Sporobolus fimbriatus* (d), *Tragus berteronianus* (d), *Cynodon incompletus*, *Digitaria eriantha*, *Ehrharta calycina*, *Eragrostis curvula*, *Setaria sphacelata*, *Tragus koelerioides*.

Biogeographically Important Taxon (Western distribution limit) Succulent Shrub: *Sarcocaulon vanderietiae*.

Endemic Taxa Geophytic Herbs: *Brachystelma huttonii*, *Ornithogalum britteniae*, *O. perdurans*. Succulent Herbs: *Haworthia cymbiformis* var. *obtusa*. Succulent Shrubs: *Ceropegia fimbriata* subsp. *fimbriata, Euphorbia inermis* var. *huttoniae*, *Rhombophyllum albanense*, *R. dyeri*.

Conservation Least threatened. Target 16%. Only small percentage statutorily conserved in Greater Addo Elephant National Park, but considerable share (12%) enjoys protection in private reserves (Kuzuko Game Reserve, Frontier Safaris Game Farm, Aylesbury Nature Reserve, Rockdale Game Ranch and Woodlands Game Reserve). About 3% transformed for cultivation. Erosion is moderate (68%), low (16%) or high (14%).

A.R. Palmer

Figure 7.12 NKl 4 Albany Broken Veld: Dense karroid vegetation with *Pappea capensis*, *Aloe ferox* and dwarf-shrub undergrowth, north of Grahamstown (Eastern Cape).

Remarks This vegetation type differs in a number of respects from those of the rest of the Nama-Karoo. Apart from climatic differences (highest rainfall, least frost), this type has a number of important species that are regarded as not important elsewhere in the Nama-Karoo. It is also the only vegetation type within the Nama-Karoo in which species such as *Enneapogon desvauxii* do not qualify as an important species.

References Acocks (1953, 1988), Palmer (1981), Dold & Hammer (2003).

10. Credits

The first version of the map for the Nama-Karoo resulted from a joint effort between L. Mucina, the late J.W. Lloyd and B. van der Merwe. Important conceptual contributions to the delimitation of the units were made by M.C. Rutherford

(particularly in NKb 2, NKu 2 and NKl 3), J.H.J. Vlok and D.I.W. Euston-Brown (NKl 3 and NKl 4), H. Bezuidenhout (NKb 2) and D.B. Hoare (NKl 4). A.R. Palmer has co-authored units NKl 2, NKl 3 and NKl 4. The introductory text (sections 1 to 8) was shaped by contributions of S.J. Milton, M.C. Rutherford, A.R. Palmer and to a small extent by L. Mucina. L. Scott has provided section 3.1. Most of the text of the descriptions was supplied by L. Mucina—all NKb units except NKb 2, all NKu units and all NKl units. In the latter, A.R. Palmer was the leading author. All descriptions were also co-authored by M.C. Rutherford, who contributed particularly to the sections on climate and conservation and to the species lists. A.P. Dold has contributed to species lists (especially list of endemic plants) in NKl 2, NKl 3 and NKl 4. L.W. Powrie and M.C. Rutherford supplied environmental and conservation-related data. All photographs except three (for acknowledgements see below) were provided by L. Mucina. M. Rouget, and others within the Directorate of Biodiversity Programmes, Policy & Planning of SANBI, provided quantitative information for each vegetation unit on conservation status and targets, areas currently conserved and areas transformed.

R.A. Ward kindly checked and corrected the geological terminology. A. Venter has checked the use of *Lycium* species in the text. E. Pienaar (opening double-page), G. Castley (NKb 2) and A.R. Palmer (NKl 4) each provided a photograph.

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Semela

Helehelele semela, kobo ya lefatshe!
Seng sa huo se tletse nuba ho pota.
Ekaba mats-watlareng, ekaba motsitseng,
Ekaba mongobong, ekaba tehlabatheng,
Baheno ba ba blome ba a jala sebele,
Ba jala ba dumeli-wa kapa ba hanelwa.

Ha o namme tjee maoto o a nka kae?
Ha o batalletse tjee maqheka o a nka kae?
Ke bua ka wena kobo ya lefatshe,
Ke bua ka wena palesa ya lefatshe,
Ha o palesa feela empa o bile o morena,
Hoba o ratwa ke batho le diphoofolo.

Ke se ke itse o hole o name semela,
Ke se itse peseletsa o peseletse kgutsana,
Nama o namele lefatshe o tlise ditharollo,
Ditharollo e be tsa tlalale ona malwetse;
Le hara malwetse ke buaka ana a kajeno:
A kajeno ke aje ha e se bona ho HIV le AIDS?

(Ka M. A. Dladla)

W.S. Matthews

Grassland Biome 8

Ladislav Mucina, David B. Hoare, Mervyn C. Lötter, P. Johann du Preez, Michael C. Rutherford, C. Robert Scott-Shaw, George J. Bredenkamp, Leslie W. Powrie, Louis Scott, Kelson G.T. Camp, Sarel S. Cilliers, Hugo Bezuidenhout, Theo H. Mostert, Stefan J. Siebert, Pieter J.D. Winter, John E. Burrows, Linda Dobson, Robert A. Ward, Marc Stalmans, Edward G.H. (Ted) Oliver, Frances Siebert, Ernst Schmidt, Khotso Kobisi and Lerato Kose

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1. Introduction

1.1 Grassland Biome and 'grasslands': What's in the Name?

This chapter is a descriptive, biogeographical and conservation account of the Grassland Biome as defined by the new boundaries in the National Vegetation Map (Mucina et al. 2005; see also Chapter 18 in this book). Its primary aim is to describe patterns and variation in the floristic and plant-functional composition and environmental parameters of plant communities in the Grassland Biome. Ideas on the origins of plant diversity and biogeographical patterns in grasslands, the problems regarding the interface with other biomes, and the topical conservation issues are also featured. This chapter extends and updates previous reviews featuring the ecology and origins of the Grassland Biome patterns (e.g. Low & Rebelo 1996, O'Connor & Bredenkamp 1997, Bredenkamp et al. 2002) by presenting new data as well as new interpretations.

The term 'grassland' is one of the most used, misused and abused terms of vegetation ecology—both by vegetation ecologists and by users of the products of their work. Obviously, any piece of land dominated by grasses can be called 'grassland'. This term then is addressing purely the structural facet of this vegetation—it is neutral and basically all inclusive. Some researchers would take this approach to global level and call all grasslands of the world 'Grassland Biome' (e.g. Coupland 1993), including grasslands of both temperate and tropical provenience. And it is here where the conceptual problems with the term 'grassland' start. Following the definitions of biomes (Rutherford & Westfall 1986, Mucina 2000), we separate two major (so-called climatically controlled) grassland types into temperate and tropical. Despite major structural similarities and often common evolutionary roots, they differ in the major features of macroclimate, structure and, from a textural point of view, in composition of life forms and species. The analytical comparisons of these two different types of grassland are justified at the broad scale (across continents), but become very problematic due to different sets of ecological and evolutionary driving forces at detailed scales (such as landscape and habitats). The (sub)tropical grasslands are considered to be part of the (sub)tropical biomes such as the Savanna Biome and Indian Ocean Coastal Belt (see the relevant chapters in this book). The warm-temperate and cool-temperate grasslands (and shrublands embedded within these) of the Highveld, Drakensberg and its northern continuation in the form of the Northern Escarpment, a whole suite of sub-escarpment grasslands, and small pockets of (most) summit sourveld composed of grasslands and savannoid bushveld (see below) make up the

Grassland Biome in our view. There are also azonal (satellite) patches of Grassland Biome communities that occur outside the main biome boundaries, such as grassy shrublands on koppies of Gh 4 Besemkaree Koppies Shrubland embedded within Nama-Karoo. The existence of these communities is linked to special habitat conditions involving shallow soils and rocky outcrops (Figure 8.2).

The extent of the Grassland Biome in Low & Rebelo (1996) and that represented here differ, especially with respect to the edaphic grasslands occurring within the subtropical biomes of South Africa. For instance, Low & Rebelo (1996) mapped Grassland Biome along the eastern coast from the Albany region, through Pondoland as far as Maputaland in the north. We consider these grasslands either secondary (Albany Coastal Belt and Transkei Coastal Belt) or edaphic (Pondoland sourveld and Maputaland coastal grasslands). In the light of this and for climatic reasons, two 'grassland' units such as SVs 4 Ngongoni Veld and SVs 5 KwaZulu-Natal Sandstone Sourveld (both classified as Sub-Escarpment Savanna, see the chapter on Savanna Biome in this book) are not considered as Grassland Biome units. Our knowledge about the primary versus secondary status of the Ngongoni grasslands is in its infancy. We hypothesise that 'ngongoni (*Aristida junciformis*) is a grass of high competitive potential and can, by virtue of building dense swards resistant to grazing damage, control recruitment of woody plants. In any case, both of the latter units are of transitional character and further insights into their ecology (especially patterns of floristic composition) and origins may result in their re-classification.

In this chapter the term 'grassland' refers to herbaceous vegetation of relatively short and simple structure that is dominated by graminoids, usually of the family Poaceae. Woody plants are rare (usually low or medium-sized shrubs) or absent or are confined to specific habitats, such as smaller escarpments or koppies. Core grassland areas usually have deep, fertile soils although a wide spectrum of soil types occurs. Precipitation is strongly seasonal and the growing season lasts approximately half the year.

1.2 Global Patterns and Local Distribution

The Grassland Biome (latitude 25° to 33° S) is part of the global Temperate Grassland Biome, which comprises the Eurasian steppes and American prairies (Great Plains) in the northern hemisphere as well as the Argentinean and Uruguayan pampas (and to an extent also grassland of southern Brazil), the temperate grasslands of the Australian Alps and the tussock grasslands of New Zealand in the southern hemisphere. The most extensive temperate grasslands in the northern hemisphere are the Eurasian steppes, which extend almost a third of the way around the world between latitudes 45° and 60° N,

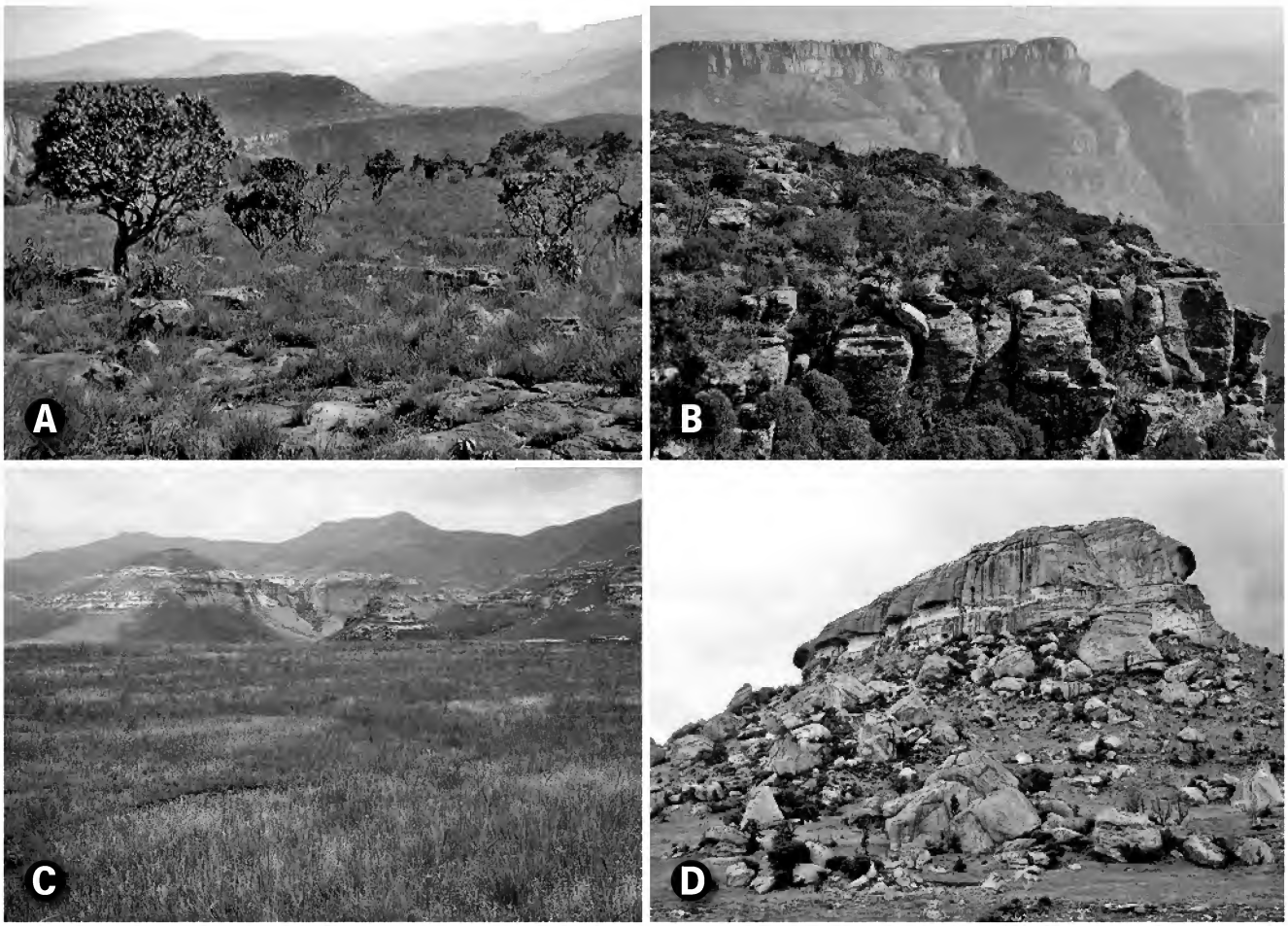

Figure 8.2 Various faces of plant communities of the Grassland Biome: A: Proteoid 'savanna' on shallow soils on quartzite with scattered *Protea rubropilosa* trees, near Aventura Blydepoort (Mpumalanga Escarpment); B: Dense shrubland of 'montane fynbos' on the Northern Escarpment of Mpumalanga; C: Typical species-rich high-altitude (2 000 m) moist grassland with *Monocymbium ceresiiforme* and numerous *Helichrysum* species on Clarens sandstone in the Golden Gate Highlands National Park near Clarens (Free State); D: Slope shrublands (with *Buddleja salviifolia*, *Euclea coriacea*, *Myrsine africana*, *Diospyros austro-africana* and *Heteromorpha frutescens* var. *abyssinica*) on a sandstone koppie near a Basotho Cultural Village in the Qwaqwa National Park near Phuthaditjhaba (Free State). All photographs by L. Mucina.

from the Dobrogea steppes near the mouth of the Danube (Romania), the northern shores of the Black Sea, through Ukraine and southern Russia, to northern Central Asia almost to the Yellow Sea in China (Manchuria). The entire Midwest of North America, ranging from the central Canadian provinces of Alberta, Saskatchewan and Manitoba to the Gulf of Mexico (30° to 55° N latitude) was covered by prairies prior to transformation. The Argentinean pampas are the largest continuous area of temperate grass steppe in the southern hemisphere and occur between 32° and 38° S.

The latitudinal differences between the two hemispheres in terms of occurrence of the temperate grasslands can be ascribed to the larger land mass concentrated in the northern hemisphere and consequently to harsher (more continental) climates governing the larger land stretches of North America and Eurasia as opposed to the more oceanic climates of the southern hemisphere.

In South Africa, the extent of the Grassland Biome can be reasonably well defined on the basis of vegetation structure in combination with environmental factors, primarily the amount of summer rainfall and minimum temperatures in winter (e.g. Rutherford & Westfall 1986). The Grassland Biome in South Africa occurs mainly on the high central plateau (Highveld), the inland areas of the eastern seaboard, the mountainous areas of KwaZulu-Natal and the central parts of the Eastern Cape. The topography is mainly flat to rolling, but also includes mountainous regions and the Escarpment. The elevation associated with grassland regions is from about 300–400 m (Gs 2 Ithala Quartzite Sourveld and Gs 9 Midlands Mistbelt Grassland, respectively) to Thabana Ntlenyana (3 482 m)—the highest mountain in southern Africa. The Lesotho Plateau and highest peaks of the Drakensberg are covered by a mosaic of grassland (Gd 8), heathlands (Gd 10) and mires (AZf 5), in which plants exhibit xeromorphic characteristics that reflect the severity of the climate at these localities. The effect of being at a high elevation in the interior of the continent results in large temperature differences from one time of the year to another and a high frequency of frost. In winter the climate on the Highveld is very cold and dry.

The occurrence of grasslands below the main Escarpment (Drakensberg), both in KwaZulu-Natal and the Eastern Cape, with floristic links to the high-altitude Drakensberg grassland, is interesting. One possible explanation for their occurrence is climatic anomalies such as the formation in winter of streams of cold air that descend from the Drakensberg and create severe climatic conditions that support frost-tolerant grasslands rather than savanna vegetation on the affected slopes and valleys.

2. Origins and Future of the Grassland Biome

2.1 Palaeoecological Patterns

Although fossil pollen records alone are not firm enough evidence for determining the time of origin of grasses, they suggest that Poaceae (the dominant element of the grasslands on global scale) and related families such as the Restionaceae, probably first developed in the Late Cretaceous (Jardine & Magloire 1965, Muller 1981, Scott & Srivastava 1984, Grass Phylogeny Working Group 2001). Earlier palaeontological studies suggested that the Poaceae was a minor component of global vegetation for several millions of years before grasslands finally became globally prominent in the Neogene worldwide (Leopold 1969, Thomasson 1988, Cerling et al. 1997) and in southern Africa (Coetzee 1978, Van Zinderen Bakker 1984, Coetzee & Rogers 1982, Scholtz 1985, Scott 1995). However, recent findings from India (Piperno & Sues 2005, Prasad et al. 2005) reported that the grasses must not only have been well diversified in Gondwana by the Maastrichian (the latest Cretaceous), but that they have also been incorporated into the diet of dinosaurs. In southern Africa the lack of terrestrial pollen records and uncertain dating of available evidence make it difficult to determine more precisely when significant grassland expansion took place (Van Zinderen Bakker 1984, Scott 1995). Cooling of global ocean temperatures is indicated in the marine isotope record (Shackleton & Kennet 1975) during the Late Miocene, and this seems to coincide with the development of modern biomes such as the Nama-Karoo, Fynbos and possibly also the Grassland Biome in southern Africa (Scott et al. 1997, Linder 2003). In southern Africa the global cooling during the Late Tertiary was accompanied by events of continental uplift, which started in the Early Miocene and culminated in significant vertical movement of up to 600–900 m in the southeastern part of the subcontinent during the Pliocene (Partridge 1997). This uplift moved a considerable area into colder higher altitudes more suitable for grasslands than for (sub)tropical savanna woodlands. Uplift in the central to western parts of the continent was much less pronounced, resulting in a sloping gradient from east to west. The effects of the gradient, enhanced by the east-west moisture gradient of the continent which was already in existence by then (Partridge 1997), may have determined the limits of grassland.

A major event in the continuing evolution of grasslands was the evolution of C_4 metabolism, which is today clearly manifested in the wide distribution of 'Kranz grasses' in the tropical and drier summer-rain regions of southern Africa (Vogel et al. 1978; see Gibbs Russell et al. 1991 for classification of the southern African grasses into various types of the C_4 syndrome). Although C_4 metabolism is most prominent in the grasses, this photosynthetic strategy is also found in some unrelated dicotyledonous families (e.g. Kadereit et al. 2003). The C_4 evolved many times during the Tertiary period (Cerling et al. 1997, Ehleringer et al. 1997, Keeley & Rundel 2003). Fossil chloridoid grasses were, however, reported from the Miocene of Kansas, and the Middle Miocene from Kenya (Thomasson et al. 1986, Retallack 1992). It is possible that plants with the C_4 strategy survived well under unique global environmental conditions including global cooling during the Neogene (Shackleton & Kennet 1975) and declining atmospheric pressures of CO_2 that developed during the Tertiary. The ability of C_4 species to bind CO_2 more effectively under dry tropical and subtropical conditions without excessive water loss furthermore give them the advantage to survive under low atmospheric CO_2 concentrations (Cerling et al. 1997, Ehleringer et al. 1997, Sage 2004). Since C_3 and C_4 metabolic mechanisms result in different degrees of ^{13}C isotope fractionation in grasses, data derived from soils, speleothems (stalagmites), fossil bones and fossil tooth enamel, can be used to trace the early history of C_4 grasses. Results suggest that grasslands dominated by C_4 grasses expanded rapidly during the Late Miocene (~ 8–4 mya) but the role of atmospheric CO_2 pressures as a possible trigger of this expansion remains uncertain. Some recent palaeoclimatic studies are at variance with the assumption that CO_2 played a significant role in the rapid spread of C_4 grasses since the CO_2 concentrations in Late Miocene were not as low as presumed earlier (Pagani et al. 1999, Pearson & Palmer 2000). Isotopes from soils, grass phytoliths and pollen evidence from the Last Glacial Maximum (LGM) suggest that at higher latitudes and altitudes C_4 grasses in southern Africa were less prominent, except in the dry southern Kalahari region where they were relatively prominent (Vogel 1978, Talma & Vogel 1992, Lee-Thorp

& Beaumont 1995, Lee-Thorp & Talma 2000, Scott 2002). Their distribution was probably limited by unfavourably low winter temperature extremes in the southern Highveld that cancelled out any advantages gained from lowered CO_2 concentrations in the atmosphere (Scott 2002).

The origin of South African grasslands (of the Grassland Biome in particular) has been the subject of a number of speculative reviews as well as serious scientific analyses (Bews 1929, Acocks 1953, Ellery et al. 1991, Meadows & Linder 1993, Scott et al. 1997, Anderson 1999, Bredenkamp et al. 2002). Several hypotheses have been formulated, especially addressing the question of lack of trees in the grassland:

1) Acocks (1953) ascribed the current extent of the grassland to recent human (agricultural) activity which destroyed large stretches of forests, considered the climatic climax in the area.

2) Tinley (1982) suggested that woody elements are excluded from grasslands by the waterlogging desiccation effect of shallow pan horizons.

3) Ellery et al. (1991) suggested that climate contributes to the maintenance of grassland by maintaining a disturbance (fire and grazing) regime that excludes woody plants.

4) Bredenkamp et al. (2002) argued that the South African grassland is a climatically controlled ecosystem in which cooler conditions at high altitudes are one of the major driving forces that prevent colonisation of trees of a generally tropical origin.

The first hypothesis has been convincingly rejected (Meadows & Linder 1993). O'Connor & Bredenkamp (1997) found the waterlogging argument incompletely supported in the Grassland Biome. The third (fire-related) hypothesis does not address the fact that both the Grassland and Savanna Biomes are fire-prone ecosystems (see also arguments in Bredenkamp et al. 2002). The case of the fourth hypothesis is still undecided, since it has not been corroborated by conclusive evidence rooted either in experimental studies of the life history of extant woody species or at least in a circumstantial manner by phylogenetic analyses.

However, these review accounts do not take into consideration the differences between the Highveld (dominated by C_4 grasses) and Drakensberg (dominated by C_3 grasses) regions of the Grassland Biome. Bredenkamp et al. (2002) did acknowledge the Drakensberg grasslands to be rich in endemic taxa and concluded that they must be primary and old, but their argument does not translate into a testable hypothesis addressing the reasons for the lack of trees in the Grassland Biome.

Firstly and most importantly, we have to admit that there are indeed woody species (including tall shrubs and trees) in some communities of the Grassland Biome. These 'shrubland' units, as featured in the section 8 of this chapter, are usually limited to special substrates showing a higher moisture input or retention ability (koppies, deep kloofs and gullies, steep slopes of incised valleys). Shrubland and tree-dominated vegetation embedded within the Grassland Biome also occurs on azonal alluvial soils. The shrubland units may be seen as relicts of past climates and vegetation patterns, and show phytogeographic links to various phytochoria. For instance the Gh 4 Besemkaree Koppies Shrubland straddles the Nama-Karoo/Grassland interface and Gh 8 Bloemfontein Karroid Shrubland may be a direct relict of the dry climate periods; the units Gm 5 Basotho Montane Shrubland, Gd 9 Western Lesotho Basalt Shrubland and Gm 2 Senqu Montane Shrubland show direct floristic links with Drakensberg grasslands and units such as Gh 12 Vaal Reefs Dolomite Sinkhole Woodland, Gh 13 Klerksdorp Thornveld, Gm 21 Lydenburg Thornveld, Gm 7 Northern Free State Shrubland and Gs 5 Northern KwaZulu-Natal Shrubland, link floristically with the Savanna Biome.

Secondly, we have to address the question of the origin of the high-altitude, endemic-rich and C_3-dominated cool-temperate grasslands in a different way than the C_4-dominated highveld grasslands, both under dry and mesic conditions. The former vegetation experiences cold and wet conditions (MAP as high as 2 500 mm in places!; with some rainshadow anomalies in Lesotho) and relatively stable climatic conditions during the periods of large climatic fluctuations of the Plio-Pleistocene. The high-altitude ecosystem did clearly react to Plio-Pleistocene climatic cycles, as suggested for instance by Scott (1989) who found that montane fynbos tended to expand to lower altitudes during the LGM. The direct data on the phylogenetic age of the endemic Drakensberg lineages, such as for *Ehrharta longigluma* (Verboom et al. 2003), and the fact that the highest number of endemics is found in young, evolutionary dynamic families such as the Asteraceae and Scrophulariaceae suggest that the speciation events which led to the Drakensberg endemism are rather recent (last 5 my).

The major grassy components of the Drakensberg grasslands are of either northern (e.g. *Festuca*, *Bromus*, *Koeleria*) or southern (e.g. *Aristida*, *Merxmuellera*, *Pentaschistis*) provenience, hence showing links to the East African (and in effect further Eurasian) mountains on one hand or to the post-Gondwanan flora of the Cape on the other. The northern track is strong and represented by nongrassy genera such as *Erica* (McGuire & Kron 2005), *Helichrysum* (Bayer et al. 2000), *Ranunculus* (Hörandl et al. 2005), and presumably many northern genera such as *Festuca*, *Geum*, *Ajuga*, *Rorippa*, *Scabiosa*, *Myosotis* and *Alchemilla*. Many of the current Drakensberg floristic constituents have been found to be firmly embedded within the Cape clades: *Cliffortia* (Whitehouse 2002, Galley & Linder 2006), Restionaceae (Linder 2000), *Leucadendron* (Barker et al. 2004), *Ehrharta* (Verboom et al. 2003), *Protea* (Reeves 2001), *Disa* (Bellstedt et al. 2001), *Phylica* (Richardson et al. 2001), *Moraea* (Goldblatt et al. 2002), *Eucomis* and *Ledebouria* (Pfosser et al. 2003), *Metalasia* (Karis 1989) and *Heliophila* (Mummedorf et al. 2005), among others. We hypothesise the same patterns also for genera such as *Aristea*, *Berkheya*, *Cotula*, *Euryops*, *Felicia*, *Hesperantha, Passerina*, *Othonna*, *Romulea* and *Ursinia*, although not excluding the possibility of two-way migrations between the Cape and Drakensberg using the Karoo Escarpment as bridge. Notable local (Drakensberg) radiations include *Schizochilus* (Linder 1980), a *Ledebouria/Resnova* alliance (Pfosser et al. 2003), *Eucomis*, *Galtonia*, *Berkheya*, *Helichrysum* and *Hypoxis*.

Interpretation of the highveld grasslands poses a different evolutionary challenge. Here endemics are very rare and, if present, are mostly found in mainly quartzite sourveld communities, showing a clear link to the flora of the Escarpment (Drakensberg in the broad sense)—see the position of the centres of endemism (CE) as defined by Van Wyk & Smith (2001) and recognised migration links such as the Magaliesberg Extension (White 1978).

Determinants for grassland ecotones in southern Africa are discussed by O'Connor & Bredenkamp (1997). From the fossil pollen evidence it is clear that marked shifts in grassland composition and grassland boundaries within the Nama-Karoo, Savanna and afromontane fynbos did occur during the glacial and interglacial periods (Scott et al. 1997). During glacial periods a considerable lowering of vegetation zones forced temperate (frost-controlled) grasslands to spread over a much wider

area, extending its limits by more than 100 km to the north of the current Highveld region. The current high-altitude grassland of the Drakensberg, dominated by C_3 grasses and fynbos elements showing the same assimilation syndrome, followed this pattern (Scott 1989). While Late Quaternary grasslands were generally more extensive, interglacial events showed grassland/savanna distributions similar to the present pattern except during peak temperature or increased CO_2-concentration events (Scott & Vogel 1983, Bond et al. 2003a). An example is a brief and limited southward expansion of savanna over the northern Highveld during the Middle Holocene temperature optimum (Scott & Vogel 1983). During the Early Holocene dry phase, karroid shrubs were prominent in the southern parts of the current Grassland Biome (Scott & Nyakale 2002, Scott et al. 2005) at the expense of grasses, but grass cover gradually increased to a maximum at ca. 2000 years BP, following the southernmost penetration of the Inter-Tropical Convergence Zone (Scott 1993, Tyson 1999, Scott & Nyakale 2002, Scott & Lee-Thorp 2004, Scott et al. 2005). Pollen records suggest the open nature of modern grasslands in the moist eastern parts of southern Africa was apparently not the result of recent anthropogenic activities (Acocks 1953), but that they were well established throughout the Holocene (Scott & Vogel 1983, Meadows & Linder 1993). Karoo expansion into the grassland areas during the 20th century was predicted by Acocks (1953), but did not realise as a result of lower grazing intensity and adequate rainfall (Hoffman & Cowling 1990).

2.2 *Climate Change Outlook*

Ellery et al. (1991) predicted (and illustrated their prediction on a simple map) that an increase of 2°C plus and 15% less precipitation than present would result in a dramatic change in the extent of the Grassland Biome. Their map has shown that basically only C_3-dominated grasslands of the Drakensberg and their northern extensions along the Northern Escarpment would survive such dramatic change. Present predictions on the extent of the Grassland Biome under climate change scenarios (Rutherford et al. 1999; see also Figure 8.3) brought on by an increase in atmospheric carbon dioxide foresee a significant reduction in the extent of the biome. Modelling scenarios predict a 3°C warmer and much drier future for southern Africa, with January temperatures increasing most in the central interior and rainfall decreasing by 5% in the north and 25% in the south. This increased temperature and aridity may obliterate the western portion of the biome and possibly a third to 55% of the biome extent may be lost. Frosts, which often kill the seedlings of woody species, will become less frequent so that woody plants will be able to invade grasslands more easily, transforming them into savanna (WWF 2001).

Other modelling studies addressed the role of fire in controlling the distribution of southern African biomes, including the Grassland Biome. Using a Dynamic Global Vegetation Model, Bond et al. (2003b) showed that exclusion of fire in regions with MAP above 650 mm would lead to an expansion of fire-sensitive forests. The regions with precipitation below 650 mm per year would show an increase of woody cover, but no trend of changing composition to forest.

3. Environmental Features

3.1 *Current Climate*

The cold, dry conditions of the Highveld region are the result of the high elevation and inland continental aspect of these areas, and these factors are important in defining the current climate of these areas. The temperate grasslands of southern Africa occur where there is summer to strong summer rainfall and winter drought. The rainfall may vary spatially from 400–2 500 mm per year and corresponds to the amount of rainfall found in other parts of the world where similar vegetation is found. Frost is a common phenomenon; the coldest periods (June–August) are exacerbated by aridity or along an increasing elevation gradient. Fog is found on the upper slopes of the Great Escarpment and seaward scarps, which support hygrophilous mistbelt vegetation. The biome has high lightning flash densities, making the incidence of lightning-induced fire a relatively high likelihood (Schulze 1984).

Studies of grassland vegetation activity from satellite data indicate that grasslands are strongly seasonal with a late summer maximum in vegetation activity and near complete termination of activity during the winter months. The areas on the western side of the biome, in the region that borders with Nama-Karoo and arid savanna, have the highest vegetation activity in February, March and April. There is a correlation between increasingly late summer to autumn maximum vegetation activity and proximity of the adjacent Nama-Karoo and arid parts of the Savanna Biome. The temperate eastern half of the Grassland Biome has a period of maximum vegetation activity in January. Some of the steeper mountain regions within this eastern region are more active in December (Hoare & Frost 2004).

3.2 *Geology, Soils and Moisture Availability*

The Grassland Biome covers large areas of the central part of South Africa. In the general geological description of the Savanna Biome (see the relevant chapter in this book) the history of the Kaapvaal Craton is summarised, which also applies here. The grasslands of South Africa cover a more significant portion of the Karoo Supergroup than the regions of the Savanna Biome, therefore somewhat more attention will be paid to this important sequence here.

The Kaapvaal Craton is the thick, stable block of continental crust that underlies most of the central, northern and eastern parts of South Africa. It was formed by the welding together of ancient blocks of crust by voluminous intrusions of granitoid plutons around 3 gya, which formed a continental crust strong and stable enough to preserve the thick volcano-sedimentary sequences of the Witwatersrand, Ventersdorp and Transvaal Supergroups as well as the massive intrusion of the Bushveld Igneous Complex.

During the Proterozoic, orogenic activity on the fringes of the craton formed the Namaqua-Natal Metamorphic Belt which marks the western and southern boundaries of the craton. In the north the Limpopo Belt forms the boundary between the Kaapvaal and the Zimbabwe Cratons.

The craton has survived several episodes of supercontinental assembly and break-up, such as those of Rodinia around 1 gya and Gondwana at the end of the Precambrian being the most recent. The Kaapvaal Craton and its adjacent orogenic belts came to support the Karoo depositional basin, one of several large basins in southern Gondwana, formed towards the end of the Carboniferous and still covered in large parts by these sediments.

The Pan-African orogenic cycle of around 550 mya resulted in the juxtaposition of several continental plates to form southern Gondwana. These have since rifted apart to form southern South America and the Falkland Islands, southern Africa, East Antarctica and the microplates of West Antarctica. Large, intra-

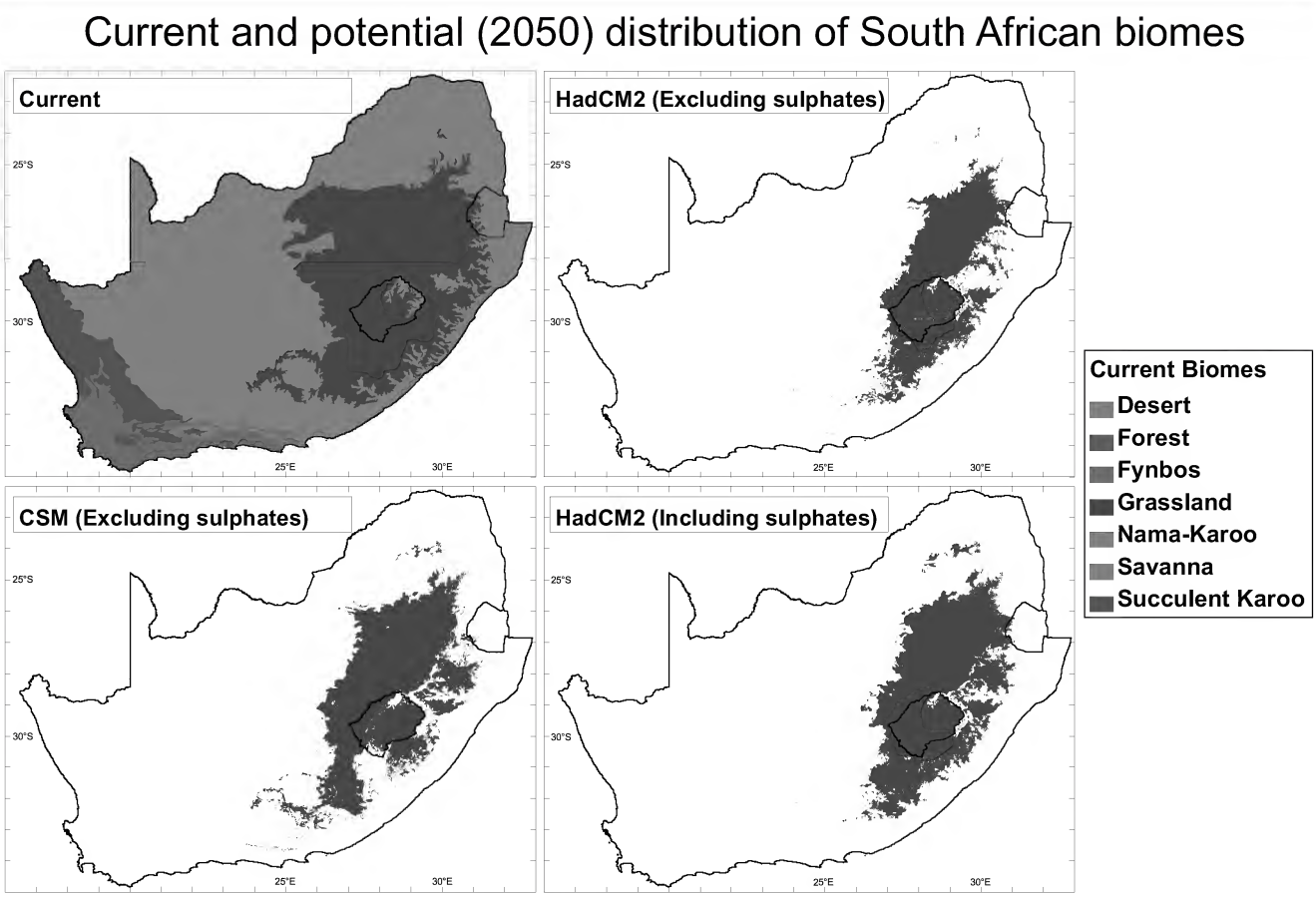

Figure 8.3 Potential distribution of the Grassland Biome with projected climate change corresponding to a doubling of CO_2 concentration from three scenarios generated by CSM and HadCM2 with and without sulphates (from Rutherford et al. 1999). The 'Current' biome coverage follows Rutherford & Westfall (1986).

continental basins formed on this land mass that at one stage, during the Early Permian, covered some 4.5 million km^2 and continued to accumulate sediments for over 100 my (Smith et al. 1993).

The supercontinent drifted over the South Pole during the Late Carboniferous, resulting in a large ice sheet that covered most of the early Karoo basin and surrounding highlands to form the widespread Dwyka Formation at the base of the Karoo Supergroup.

Smith et al. (1993), in their review paper on the Karoo-aged basins of southern Africa explain how subduction of the palaeo-Pacific plate below southern Gondwana resulted in the formation of the 'Gondwanide' mountains that deformed and truncated the southern rim of the Karoo basin. This folding of the older Karoo sediments is clearly visible in the southernmost parts of the Karoo. Furthermore, sediments derived from the erosion of this mountain chain accumulated in large deltas that built into an inland sea to form the Upper Ecca Group. These broad delta plains together with a humid climate promoted the formation of peat which would later form the vast coal reserves of southern Africa.

Overlying the Ecca sediments are those of the Beaufort Group that were deposited on broad alluvial plains during a time when the climate warmed and dried as the supercontinent drifted towards lower latitudes. These Permo-Triassic times saw an abundance of reptilian fauna; particularly prominent were the therapsids or 'mammal-like reptiles' of which the Karoo preserves the longest and most complete record (e.g. Cluver 1978, Smith et al. 1993).

Aridification continued in the upper Karoo Sequence during the Jurassic and culminated in the deposition of dune sands on a playa-like environment. These sediments of the Elliot and Clarens formation were eventually covered by thick outpourings of basalt of the Drakensberg Group which brought the Karoo sedimentation to a close. This volcanic activity occurred basin-wide during the Jurassic and included the intrusion of Karoo Dolerite dykes that form a characteristic feature of the Karoo and some of the grassland landscapes. These flood basalts formed as a result of the initial stages of the rifting apart of Gondwana during the Late Jurassic to form the more familiar arrangement of the continents today. For this reason, part of this flood basalt province is found on the Antarctic continent, where it is known as the Ferrar traps. The estimated volume of lava erupted in the Karoo basin, including the Ferrar basalts, is 2.5×10^6 km^3 (Wignall 2001), which would have had a profound effect on the global climate and life on earth at the time.

Moisture availability is the major factor which can be used to divide the Grassland Biome into two classes (Ellery et al. 1995). Moist grassland consists of sour grasses, leached and dystrophic soils and high canopy cover, high plant production and high fire frequency. Dry grassland has sweet, palatable grasses, soils are less leached and are eutrophic and canopy cover, plant production and fire frequency are lower than in moist grasslands. Sweet grasses, mostly belonging to the subfamily Chloridoideae, have a lower fibre content and maintain a higher above-ground nutrient content in winter than sour grasses, belonging mostly to the subfamily Panicoideae (Andropogoneae), thus making them more palatable to stock (Rutherford & Westfall 1986).

Sour grasslands (sourveld) in South Africa are generally found at higher altitudes—usually linked to high water supply, and where parent material gives rise to soils with a low base status. Sweet grasslands (sweetveld) occur mainly at lower altitudes, in areas with lower water supply, and where parent material gives rise to soils with a high base status.

3.3 Fire

Grassland is a fire-prone ecosystem, hence fire is vital to the maintenance of both its structural and textural patterns (Edwards 1961, 1968, Granger 1976, Tainton 1981, Everson 1985, Bainbridge 1993, O'Connor & Bredenkamp 1997). Dynamic vegetation models indicate that without fire most of the eastern half of South Africa would be covered in trees (Bond et al. 2003b). Fire exclusion studies indicate that in the absence of fire there is a succession trend towards shrublands with fynbos affinities and then to forest in grasslands with annual rainfall of more than 650 mm. In grasslands with less than 650 mm of annual rainfall, the exclusion of fire leads to an increase in tree density without a change in species composition (Figure 8.4). Grassland vegetation with less than 650 mm annual rainfall is therefore climate-limited, whereas those areas with more than 650 mm annual rainfall are fire-limited and are in a meta-stable state, with alternate climate-dependent states (Bond et al. 2003b).

The key components of a fire regime are the frequency, seasonality and intensity of fires (Gill 1975). Fire in grasslands occurs every 1–4 years and, in montane grasslands, occurs mostly in late winter from July to September (Le Maitre & Midgley 1992). Fire intensity depends on fuel moisture, air temperature and wind speed. Lightning is the primary natural source of ignition for grassland fires. The Grassland Biome has a high frequency of lightning strikes per area of ground and thus natural fires that maintain grassland dominance over woodland are a natural ecological component of the landscape. Natural breaks such as drainage lines and man-made structures such as roads pose barriers to the large-scale fires, assisting in creation of landscapes composed of grassland patches in different stages of recovery (Figure 8.5).

The dominant grasses of the cool, temperate grasslands of South Africa are from the Panicoideae (Gibbs Russell 1988), specifically from the tribe Andropogoneae, including genera such as *Andropogon*, *Trachypogon*, *Heteropogon*, *Cymbopogon*, *Dihetero-*

L. Mucina

Figure 8.5 Grassland mosaic created by wild fire in the Golden Gate Highlands National Park near Clarens (Free State).

L. Mucina

L. Mucina

Figure 8.6 Fire sweeping through *Acacia sieberiana* var. *woodii* savannoid grassland below the Van Reenen's Pass on a slope near Tugela Toll Plaza (KwaZulu-Natal).

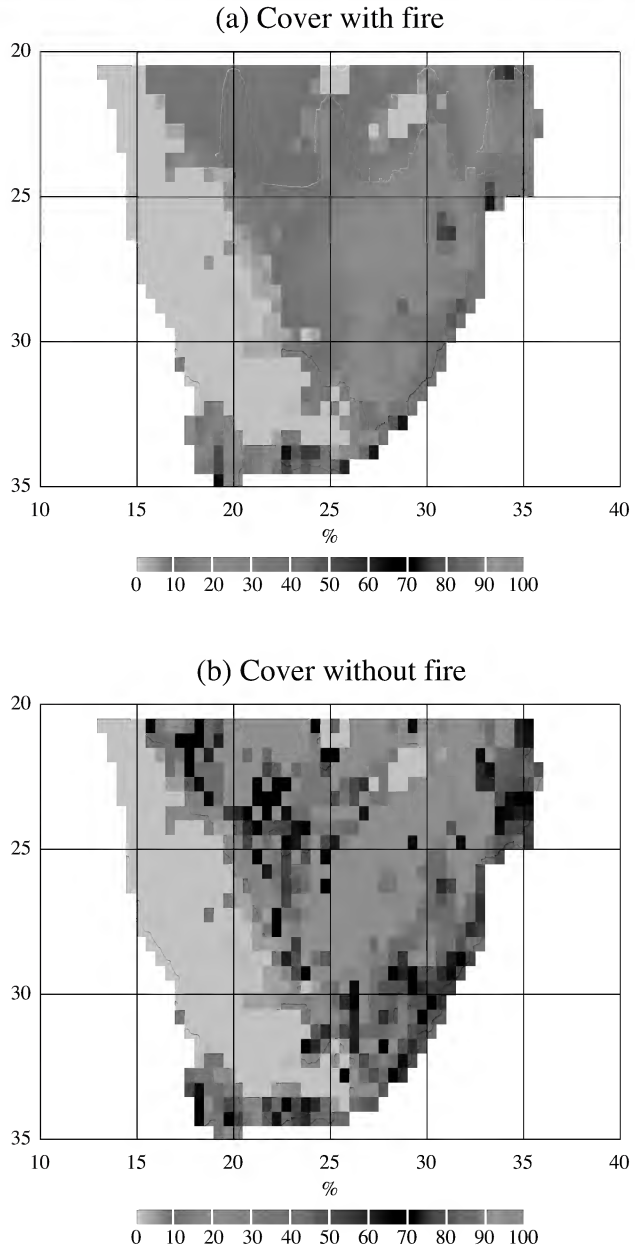

Figure 8.4 Simulated tree cover (%) using the Sheffield Dynamic Global Vegetation Model. The model is a global-scale tool, simulating carbon and water dynamics and structure of vegetation using input data of climate, soil properties and atmospheric CO_2. It also includes a fire module that approximates fire frequency based on empirical relationships between moisture content of plant litter (which can be simulated from climate) and fire return intervals. The upper figure (a) features modelling with fire included, while the lower picture (b) shows the modelling result with fire excluded. (After Bond et al. 2003b, Figure 4; courtesy of the authors and the South African Association of Botanists.)

pogon, *Monocymbium*, *Tristachya*, *Schizachyrium*, *Themeda* and *Hyparrhenia*. The low nutritional value and high tannin content (Ellis 1990) of these grasses cause slow decomposition rates and, therefore, the build-up of highly flammable fuel (Bond et al. 2003b). They also produce basal tillers, which make them susceptible to shading by old growth that persists from previous seasons (O'Connor & Bredenkamp 1997) and they therefore have an obligate dependence on defoliation. The dominant species of andropogonoid grasses often decline rapidly in importance in the absence of burning (Tainton & Mentis 1984), a trend also reported from North and South America, Australia and Southeast Asia (Stott 1988, Silva & Castro 1989, Morgan & Lunt 1999). Woody species that are often found in temperate grasslands include small trees such as *Acacia sieberiana* var. *woodii* and species of *Protea* and *Cussonia* that have thick, fire-resistant bark that allows them to tolerate low-intensity (skimming), high-frequency fires (Figure 8.6). The proteas are furthermore serotinous but, in grasslands, almost all resprout to recover from fire rather than reseed (Le Maitre & Midgley 1992). Fire stimulates flowering in grassland geophytes (Frost 1984).

3.4 Grazing Pressure

Grazing has a major influence on canopy structure in grasslands as well as on species composition. The grass plant is well adapted to defoliation by grazing, fire or mowing: the basal meristems of grass leaves enable regrowth after defoliation and draw on carbohydrate reserves from the stem bases or rhizomes (Rutherford & Westfall 1986). Although this adaptation is effective, excessive or frequent defoliation can deplete reserves, with adverse consequences (Rutherford & Westfall 1986). Some species respond to grazing pressure by changing growth patterns (often preferred grazing species) thus allowing niche displacement in relation to grazing intensity. Grazing can alter plant density/size, plant longevity, community composition and diversity, vegetation response to climate patterns, and vegetation response to other abiotic factors such as soil depth. Besides defoliation, heavy grazing can affect grass seed production negatively. Grazing pressure (including density of grazers and composition of grazing herds) varies from farm to farm, dramatically shaping the overall appearance of grasslands by creating the so-called fence-line effect (Figure 8.7).

Degradation of grasslands, including the spread of karroid shrubland into the Grassland Biome, has been blamed on high stocking rates of domestic livestock in commercial farming areas. Many communal grazing lands are commonly stocked at 3–4 times the recommended stocking rates for commercial farming and, although these areas appear to be degraded, they have remained in a stable and apparently productive state for decades. Heavy grazing in the communal areas of the Transkei appears to have reduced overall species richness (Hoare 2002) and changed species composition to less palatable grasses, especially on nutrient-poor soils (Owen-Smith & Danckwerts 1997).

High concentrations of indigenous herbivores can also alter plant species cover and composition. The primary difference between domestic livestock and wild herbivores is scale-related (Owen-Smith & Danckwerts 1997): the provision of supplementary fodder in commercial farming areas during drought periods prevents animal mortality so that grazing pressure is maintained during all seasons, whereas wild herbivore impacts are more spatially and temporally heterogeneous.

Prominent wild ungulate herbivores in highveld grasslands include black wildebeest (*Connochaetes gnou*), blesbok (*Damaliscus dorcas phillipsi*), extinct quagga *(Equus quagga)*, springbok (*Antidorcas marsupialis*) and eland (*Taurotragus oryx*; Figure 8.8*)*. Historically, these species may have seasonally moved along rainfall gradients in areas near the Drakensberg, occurring near water sources in the dry season and away from water sources during the wet season. The abundance and grazing impact of small mammals may exceed that of ungulates, but the distribution of the former is patchy and abundances may vary considerably over time (Owen-Smith & Danckwerts 1997). Prominent species in grasslands include porcupine and several species of hare. Other wild herbivores in grasslands include

L. Mucina

Figure 8.7 Typical fence-line effect (former 'national' border between the Cape and Transkei) marking the difference between a commercial farm with well-developed *Themeda triandra* grassland (left) and communal land with invading unpalatable *Euryops floribundus* (Asteraceae) near Elliot (Eastern Cape).

M.C. Lötter

Figure 8.8 Eland (*Taurotragus oryx*) grazing in a grassland near Vryheid (northern KwaZulu-Natal).

leopard tortoises, hinged tortoises, grasshoppers and harvester termites. Although the last-named are strictly detritivores, they can cause severe denudation of grasses during drought periods. Avian granivores strip and consume many grass seeds from inflorescences. Granivory appears to affect species with large seeds, e.g. *Themeda triandra* and *Heteropogon contortus*, more than those with small seeds, e.g. species of *Aristida* (Owen-Smith & Danckwerts 1997).

Different kinds of herbivores may have different and complementary effects on different plant species. Domestic grazers, wild ungulates, small mammals and insects favour different grass species and may be sensitive to different secondary chemicals. Different plant defences are effective against different herbivores and no single deterrent is effective against all herbivores (Owen-Smith & Danckwerts 1997).

4. Vegetation Structure and Texture

Grasslands are structurally simple and strongly dominated by grasses (Poaceae). The canopy cover is moisture-dependant and decreases with lower mean annual rainfall, but is influenced by the amount and type of grazing and by the presence of fire. Minimum temperature plays a decisive role in structurally distinguishing temperate grasslands from those where frosts are rare (Walker 1993). Woody species, where they occur, are limited to specialised niches/habitats. Forbs form an important component of grasslands and, although not usually dominant, probably contribute more to the species richness of grasslands than grass species do. Annuals do not form a large component of the vegetation, but are important in filling gaps where disturbance occurs.

Above ground, there are two primary structuring forces within grasslands that operate in opposite directions: competition for canopy space (i.e. light) and ungulate grazing pressure (Diaz et al. 1992). Besides herbivory, rainfall (plant available moisture), soil type (nutrient availability) and fire are further major determinants of grassland structure and these are strongly interactive (Walker 1993). Diaz et al. (1992) identified six species modes (similar to functional types) in which sustained occupation of above-ground space increases along a gradient from annuals to prostrate stoloniferous plants to rosette plants with below-ground storage organs to small graminoids to medium-sized graminoids to tussock grasses. Silvertown et al. (1992) demonstrated that heavy grazing conditions (reduced cover of dominant species) foster seedling emergence in annual dicotyledons, but also jeopardise subsequent survival (by grazing at various stages of life cycle), which is why productive grassland communities may contain few palatable dicotyledons since few of them can successfully complete their life cycle.

Grass species diversity of the subfamily Panicoideae is higher in the Grassland Biome than that of the Arundinoideae, Chloridoideae or Pooideae. The Panicoideae are a major C_4 photosynthesis group and tend to predominate in the Grassland Biome and moist parts of the Savanna Biome of South Africa (Vogel et al. 1978, Gibbs Russell 1986, Gibbs Russell et al. 1991). The most abundant

component of the Panicoideae is from the tribe Andropogoneae (Gibbs Russell et al. 1991). The Pooideae, an exclusively C_3 subfamily, have maximum diversity and abundance only at high altitude and in moist habitats and are important in the high Drakensberg region (Vogel et al. 1978, Gibbs Russell 1986, Rutherford & Westfall 1986).

5. Biodiversity and Biogeographical Patterns

5.1 *Phytochorological Considerations*

The Grassland Biome in South Africa coincides with two major phytochoria (White 1983): Kalahari-Highveld Regional Transition Zone and Afromontane and Afroalpine Region. The mountainous landscapes along the Northern Escarpment are within the Afromontane and Afroalpine Region of White (1983). These areas also include the most temperate components of the biome, both floristically and climatically. The largest part of the Grassland Biome boundary interfaces with the Savanna Biome, an area considered to be primarily linked to White's (1983) Kalahari-Highveld Regional Transition Zone and Zambezian Regions and, therefore, of more tropical affinity. The Grassland and Savanna Biomes both have strong rainfall seasonality and very similar summer-rainfall patterns and amounts. The major environmental factor separating them is summer aridity in combination with winter minimum temperature that leads to 'phanerophyte exclusion' (Rutherford & Westfall 1986), resulting in the absence of a major woody component. The clear floristic link between the Grassland and Savanna Biome (see also discussion on the origins of the Grassland Biome above) has been corroborated in the phytochorological classification of Takhtajan (1986). Most of the Grassland Biome as defined in our study falls within Takhtajan's Sudano-Zambezian Floristic Region (with tropical connotation). The Sub-Escarpment Grasslands are classified within the Uzambara-Zululand Floristic Region—a view which we do not share. The transitional Karoo Escarpment Grassland falls within the Karoo-Namib Floristic Region or, after current revisions (see the chapter on Nama-Karoo Biome in this book), in the Nama-Karoo Floristic Region. We do not subscribe to this view either and suggest that the boundaries of phytochoria on the Karoo/Grassland interface are revised.

The drier western and southwestern boundary of the Grassland Biome interfaces with the Nama-Karoo along a zone of high rainfall uncertainty. This region also represents a gradient of decreasing rainfall and lower elevation with distance westwards. It has been hypothesised that overgrazing by domestic livestock has led to the eastward expansion of the Nama-Karoo into the Grassland Biome through the reduction of perennial grass cover in this zone (Acocks 1953), but an alternative hypothesis suggests that cyclic shifts in rainfall amount and seasonality promote a dynamic change in the relationship between perennial grasses and karoo bushes (Hoffman & Cowling 1990).

There is little interface between grassland and fynbos, but a dynamic relationship exists between these two vegetation types and satellite grasslands occur in the Fynbos Biome in the mountains of the Eastern Cape and satellite fynbos occurs within the grasslands of the Northern Escarpment region, especially on nutrient-poor soils in areas protected from fire. Numerous studies have demonstrated the floristic linkages between the Fynbos Biome, the mountain regions of the Grassland Biome and afromontane regions further northwards in Africa (e.g. Weimarck 1934, 1940, Goldblatt 1978, Rourke 1980, Linder 1983, Linder & Ellis 1990, Hartmann 1991, Linder et al. 2005, Galley & Linder 2006). The number of Cape species becomes less as the distance from the Fynbos Biome increases and the number of afromontane species increases.

Grassland interfaces with indigenous afrotemperate forests in many places, but especially along the Escarpment (Von Maltitz et al. 2003, Geldenhuys & Mucina 2006), where forest patches may be found on steep, south-facing slopes with high soil moisture or in deep, sheltered, moist gullies. In these topographic positions they survive the dry periods and from these positions they expand further along the slopes. As already argued (see Chapter 12 on forests in this book), fire plays a major role in forest/grassland border dynamics. Vegetation models suggest that without fire most of the eastern half of South Africa would be covered by dense tree-dominated vegetation (Bond et al. 2003b).

5.2 *Endemism*

Five Centres of Plant Endemism (CEs) have been identified within the borders of the Grassland Biome (Van Wyk & Smith 2001): Drakensberg Alpine, Barberton, Wolkberg, Sekhukhune and Soutpansberg. Only the Drakensberg Alpine CE and Wolkberg CE falls completely within the Grassland Biome, while the other CEs are shared with the Savanna Biome (Figure 8.9). As suggested by unpublished data sources and the descriptive accounts of vegetation units in this chapter, high concentrations of local (confirmed to only a single vegetation unit as defined in this study) or regional (shared by several geographically bordering and ecologically similar vegetation units) endemics are also found in the KwaZulu-Natal Midlands (C.R. Scott-Shaw, unpublished data), Sneeuberg Mountains on the Karoo Escarpment (N. Barker & R. Clark, unpublished data), low Drakensberg (L. Mucina, M.C. Lötter & C.R. Scott-Shaw, unpublished data), and in the mountainous surrounds of Lydenburg (M.C. Lötter, unpublished data). Detailed analyses of the local floras of these regions as well as their phytogeographical links may reveal the existence of several new centres of endemism. The most extensive and most endemic-rich phytochorion of all the above is the Drakensberg Alpine CE with about 13% of endemism, counting about 334 endemic taxa and five endemic genera (Van Wyk & Smith 2001, Carbutt & Edwards 2004, 2006). There are a number of species linking the core of the Drakensberg Alpine CE (defined in our study by the extent of Gd units as currently delimited) with the Midlands, especially with the mountains lying south and southeast of the Escarpment in a triangle approximately defined by Himeville, Kokstad and Matatiele (and, importantly, also including the Ingeli Mountain). The vegetation map of these high-altitude islands (interestingly indicated by Carbutt & Edwards 2004 as parts of their Drakensberg Alpine CE) should be reconsidered and perhaps included in one of the Gd units in future. Species showing this distribution pattern are designated as Dg (Drakensberg/Griqualand East) and include, for instance, *Erica algida*, *E. thodei* and *Berkheya pannosa*.

The currently recognised centres of endemism are either linked to high altitudes (Drakensberg Alpine, Wolkberg) or special substrates, among which quartzites and rare ultramafics (Barberton and Sekhukhune regions) play the major role. Another interesting aspect of the location of the CEs is the fact that they occur in the Grassland-Savanna 'tension' zone. Here the endemic-rich grassland vegetation is usually a 'summit sourveld'—forming an elevated island surrounded by the 'hot sea' of the subtropical savanna vegetation. The Drakensberg Alpine CE may be the hub of this 'sourveld phenomenon', showing a number of distinct floristic and phytogeographical links westwards (towards Capensis via the Escarpment), northwards (via the low Drakensberg) towards the Northern Escarpment and fur-

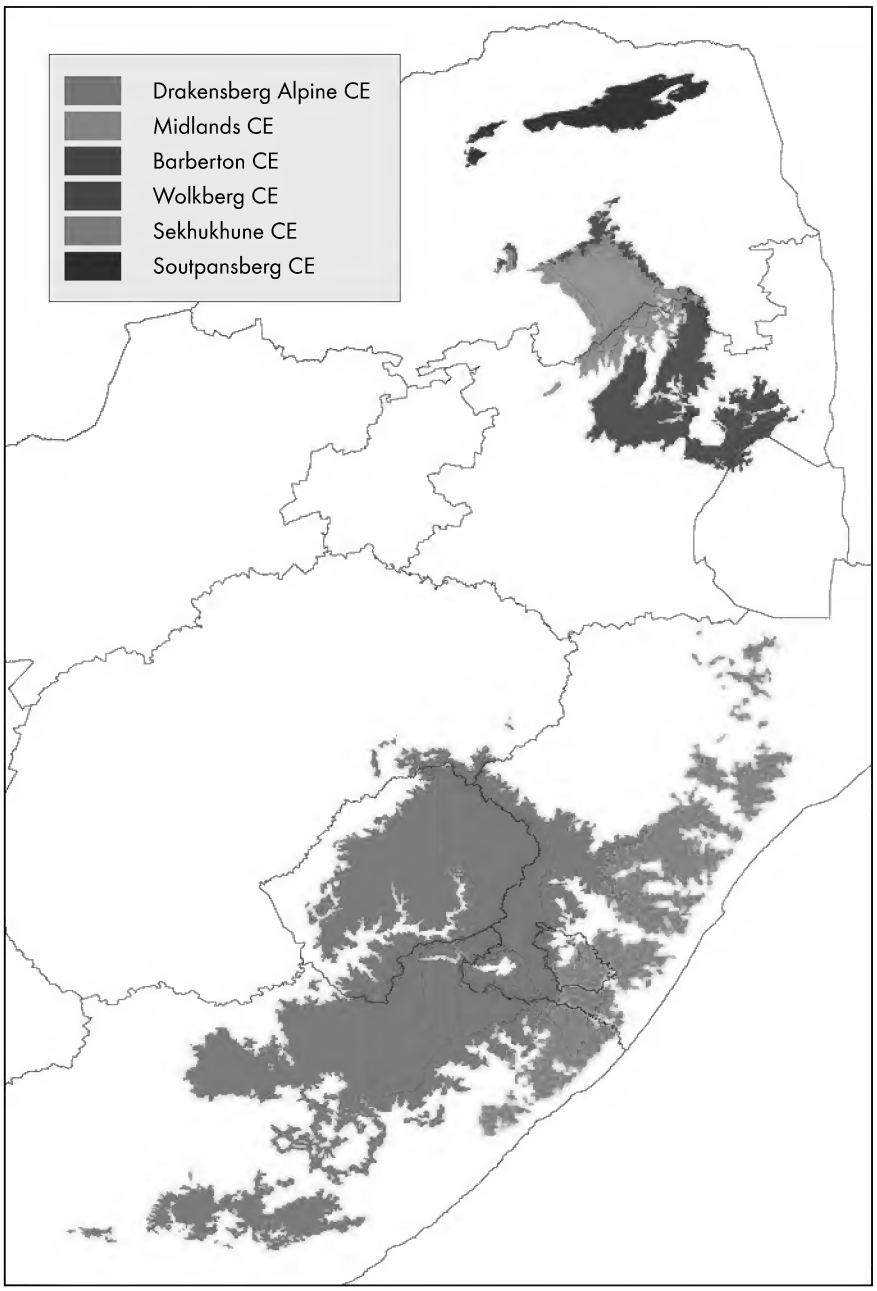

Figure 8.9 Six putative centres of endemism embedded within the Grassland Biome or straddling borders of the Grassland and Savanna Biomes.

ther north as far as the high mountains of eastern Zimbabwe (also shared with Mozambique in the Chimanimani Range) and southeastwards (at lower altitudes) towards the midlands of Transkei and KwaZulu-Natal and reaching the lowest altitude in Pondoland (see discussion in Carbutt & Edwards 2001, 2004). Van Wyk & Smith (2001) mentioned the multiple links between these phytochoria as well as with other 'summit sourveld' grasslands of the northern provinces several times. We believe that the definition, hierarchical position and demarcation of the relevant phytochoria of the current CEs within the Grassland Biome require revision. As a contribution to these future developments, we have introduced the concept of 'Northern sourveld endemics'. This category encompasses species shared by several currently recognised CEs and being confined to grassland habitats within these CEs.

It is also of significant importance to confirm that the core of the Grassland Biome (dominated by C_4 grasses) contains no regions of endemism, indicating either a relatively young age of these grasslands and/or dramatic (recurrent) climatic changes causing repeated floral extinctions (see the discussion on the evolution of the Grassland Biome above).

There are 34 grass taxa that are endemic to the Grassland Biome of South Africa of which 13 are from the subfamily Arundinoideae and 11 from the Pooideae (Steenkamp et al. 2002). The Arundinoideae forms the dominant component of the winter-rainfall region of South Africa and the Pooideae are only occasionally dominant in high-altitude grasslands (Gibbs Russell 1986). It is unknown what the total levels of endemism amongst other taxa in the Grassland Biome are, but upper and lower values can be estimated. Assuming the proportion of endemism is equal across all taxonomic groups, then the number of endemics other than grasses may be 179. Of the grasses, most of the endemics are found only in the high-altitude montane grasslands and only five are found in highveld grasslands (Steenkamp et al. 2002). Only two endemic grass genera are known from the Grassland Biome so far—*Polevansia* and *Catalepis*.

Among the herbs, high endemism occurs in the orchids—of 161 orchid taxa found in the Grassland Biome, 67% are endemic (Linder et al. 2005). There are seven orchid clades identified in (but none restricted to) the flora of the Grassland Biome; the most speciose subtribes are the Habenariinae (55 taxa), Disinae (41 taxa) and Coryciinae (31 taxa; Linder et al. 2005). Generic endemism in herbs is not very high compared to that in the biomes of the winter-rainfall regions of South Africa. The endemic herb genera are concentrated especially in the Drakensberg (including the Low Escarpment and Northern Escarpment) and include: *Anisopappus*, *Arrowsmithia*, *Callilepis*, *Cymbopappus*, *Eumorphia*, *Glekia*, *Heteromma*, *Hilliardia*, *Inulanthera* and *Macowania* (Asteraceae), *Rhodohypoxis* (Hypoxidaceae), *Huttonaea*, *Dracomonticola* and *Schizochilus* (Orchidaceae), *Guthriea* (Achariaceae), *Galtonia* (Hyacinthaceae), *Glumicalyx* and *Strobilopsis* (both Scrophulariaceae), *Peltocalathos* (Ranunculaceae), *Hemizygia* and *Thorncroftia* (Lamiaceae), *Frithia*, *Khadia*, *Mossia* and *Neohenricia* (Aizoaceae), among others. Very speciose genera such as *Senecio*, *Helichrysum*, *Erica*, *Berkheya*, *Delosperma*, *Wahlenbergia*, *Ledebouria* and *Disa* also contribute a high number of species-level endemics (Figure 8.10).

5.3 Species Diversity Patterns

Data on patterns and maintenance of species richness in the grasslands of South Africa are relatively sparse (Cowling et al. 1989). A 100 m^2 plot in high-altitude grassland of the Eastern Cape or KwaZulu-Natal may contain 9–39 species within veg-

Figure 8.10 A selection of grassland endemics. A: *Senecio macrospermus* (Asteraceae), B: *Eucomis bicolor* (Hyacinthaceae), C: *Zaluzianskya microsiphon* (Scrophulariaceae), D: *Tulbaghia leucantha* (Alliaceae), E: *Haplocarpha nervosa* (Asteraceae), F: *Nerine bowdenii* (Amaryllidaceae), G: *Kniphofia caulescens* (Asphodelaceae), H: *Aloe albida* (Asphodelaceae). The taxa A–C, F and G are endemic to the Drakensberg CE, E is endemic to the Grassland Biome and H is endemic to the Barberton CE. Photographers: A–F: L. Mucina, G: M.C. Rutherford, H: M.C. Lötter.

etation with a single uniform grass layer (Eckhardt et al. 1996a, Hoare 1997). This may increase by 10 or more species in specialised habitats where multistructural vegetation is able to develop, e.g. rocky outcrops (Hoare 1997). There is a curvilinear relationship between species richness and the amount of surface rockiness in temperate grasslands, with intermediate amounts of surface rock containing the highest number of species (Hoare 2003). A 1 000 m^2 plot may contain 55–100 species. At a regional scale, grasslands have a high alpha diversity and a moderate gamma diversity; the Highveld region on its own has almost 4 000 species and contains centres of diversity for many speciose genera (Cowling et al. 1989).

High local species richness in grasslands is difficult to understand, considering the limited growth form richness in this vegetation. A number of explanations have been put forward to explain how so many species within the same functional guild coexist. These include the effects of differential responses to grazing, fire and local disturbance on competitive hierarchies, phenological separation and resource partitioning in mesic grasslands and the dampening of long-term competitive interactions due to the effects of variable climate patterns in semi-arid grasslands (Cowling et al. 1989). Management can have a strong effect on species richness and composition of grasslands by affecting competitive interactions amongst species. For example, communally managed grasslands of the Eastern Cape have 24 species per 100 m^2 plot in comparison to 34 species in commercially managed rangelands where all other environmental factors are constant. These poorly managed grasslands also have more exotic species, are dominated by forb species rather than grasses and have a higher dominance by individual species (Hoare 2002).

Species turnover in grasslands may be relatively high where topographical and environmental gradients are steep and, in the mountains and the Escarpment region, there may be high rates of turnover due to both rainfall and elevation: complete turnover of species may occur for every 400 mm change in amount of mean annual rainfall or for every 400 m of change in elevation (Hoare 2003). These high rates of beta diversity permit coexistence of species at a landscape level that contributes to the overall richness of the biome.

6. Transformation and Conservation

6.1 Patterns of Land Use and Threats to Grasslands

Land cover data (Fairbanks et al. 2000) indicate that almost 30% of the Grassland Biome of South Africa has been permanently transformed, primarily as a result of cultivation (23%), plantation forestry (4%), urbanisation (2%) and mining (1%). A further 7% has been severely degraded by erosion, agricultural improvement and other factors. Significant parts of the remaining vegetation may be secondary lands or may be degrading by gradual processes such as woody encroachment, but no exact statistics are available. Ground surveys of land cover in areas of the Eastern Cape with dense rural populations indicate that up to 80% of the 'natural' grassland may be old fields and therefore of a secondary nature (D.B. Hoare, unpublished data), suggesting that, at least in some of the worst-affected areas of South Africa, as little as 15% of the natural grassland is still in a natural state. This is consistent with statistics in Low & Rebelo (1996) in which the average level of transformation for all grassland types is given as 58%. Of additional concern is the fact that those areas of grassland that are untransformed are highly fragmented and that as much as half the remaining areas of grassland may be composed of fragments of only a few hectares in extent.

Future threats to the vegetation of the Grassland Biome include continuous transformation by existing land uses due to the suitability of many areas of the biome for important economic activities and the threat of climate change, which may reduce the extent of the biome by up to 55% (see section above). Highveld grassland is particularly suitable for agricultural activities, and has significant mineral deposits and high urban densities. The latter two are likely to expand with economic growth in the future. The Escarpment and mountain regions are threatened mainly by afforestation with exotic *Pinus* and *Eucalyptus* species. It is estimated that this land use has doubled in the last ten years (Fairbanks et al. 2000) and that as much as 200 km^2 of grassland in these regions are lost to forestry alone every year (Van Wyk 1998). Furthermore, most of the communal land in the Grassland Biome occurs in the Escarpment region and is susceptible to overgrazing and the associated degradation.

The Grassland Biome contains 640 Red List species (Hilton-Taylor 1996, excluding species categorised as 'not threatened') of which 136 are threatened with extinction and six are already extinct. There are only nine grass species on this list.

6.2 Conservation Activities

There are numerous small reserves in the Grassland Biome, but together they make up only 2.2% of the biome area (Low & Rebelo 1996). This is not evenly distributed and the Highveld region is very poorly conserved in comparison to the Northern Escarpment and mountain regions. Nature reserves include Suikerbosrand, Rustenburg, Golden Gate, Qwaqwa, Blyde River Canyon and various dams. The reserves around dams are especially contentious since they were created around man-made structures for recreational purposes and are not based on systematic conservation principles.

The most important current conservation initiative under development is the Maloti-Drakensberg Transfrontier Park, which incorporates the Natal Drakensberg Park and the Drakensberg Mountains World Heritage Site declared in November 2000. The South African component of this Transfrontier Park is the uKhahlamba-Drakensberg Park, which contains spectacular natural landscapes and a rich biodiversity (Zunckel 2003). A total of 2 153 plant species have been recorded for the park (Derwent et al. 2001), of which more than 400 are endemic or near-endemic (Van Wyk & Smith 2001). Most of these are associated with the grasslands. There are 32 bird species, 11 mammal species and 40 frog species that are endemic to southern Africa that occur in the park and it is considered to be one of the eight major centres of diversity for reptiles and amphibians in southern Africa (Derwent et al. 2001).

Another conservation initiative being considered is the Pondoland National Park, which includes an area that has not been well conserved although deserving of special attention due to high diversity and endemism as well as exceptional scenic beauty. The area suggested for the proposed Pondoland National Park would include most of the Pondoland Centre of Floristic Endemism, which has about 1 800 plant species of which more than 120 are endemic or near-endemic (Van Wyk & Smith 2001).

The most significant conservation work being undertaken outside major conservation areas in the grasslands of southern Africa is often focused on highly threatened species, such as the blue swallow, various crane species, black and white rhinos

or Rudd's lark. The basis for these conservation efforts is the awareness that managing habitats is the key to managing the threats to these species since habitat loss is the primary reason for their decline. WWF South Africa plays a key role in supporting these initiatives. At the time of writing, a National Grasslands Initiative for conserving grasslands was in the process of being formalised. This is a nationwide South African project aiming at co-ordination of ongoing conservation planning within the grasslands, to identify gaps in these conservation plans, to highlight conservation priorities, and to ensure the successful implementation of these plans within the existing political and socio-economic framework of the region (Reyers & Tosh 2003). The project recognises that promoting off-reserve conservation on privately or communally owned land will have to form a major component of sustainable land management. Initial indications are that the project enjoys wide support among administrators at various levels in government, NGOs, academic institutions, agricultural bodies and international donors. An all-inclusive group will contain landowners as well and, once this has been achieved, this project should have all the components required to address sustainable long-term management of the Grassland Biome.

7. Subdivision of the Grassland Biome

The division between dry and moist grassland can be made on the basis of annual rainfall, with 500–700 mm rainfall marking the boundary. This corresponds to the dry limit of 500 mm annual rainfall of the Argentinean pampas and is consistent (under considerations of the role of parent material and soil nutrients) also with divisions of the grasslands in South Africa into sweetveld and sourveld (Huntley 1984, Ellery et al. 1995, Bond 1997). Above 600 mm of rainfall, sour andropogonoid grasses predominate, whereas below 600 mm sweet chloridoid grasses are more common. The 600 mm rainfall limit also corresponds to soil nutrient factors: plant growth in moist grasslands with dystrophic soils is mostly macronutrient-limited and in dry grasslands with eutrophic soils it is mostly water-limited. These ecological factors affect a number of other patterns found in grasslands, including, for example, diversity relationships within grassland plant communities which are explained by entirely different suites of factors in moist versus dry grasslands (D.B. Hoare, unpublished data) and structure, where moist grasslands are dependent on fire for maintaining structure, unlike dry grasslands (Bond et al. 2003b).

Altitude has a strong influence on most climatic variables. Generally, an increase in altitude corresponds with a decrease in temperature and an increase in rainfall. Mountains also have an orographic influence on rainfall, escarpment zones usually experiencing increased rainfall and mists, and, depending on aspect, cause an increase or decrease in mean daily insolation levels. The major subdivisions of the Grassland Biome are based on gradients of altitude and moisture. Subdivisions of these groups were made on the basis of correlating floristic and environmental factors. The major subdivisions are the four bioregions described below.

8. Description of Vegetation Units

Drakensberg Grassland

Drakensberg grasslands are found primarily associated with the Great Escarpment of the Drakensberg region, including Lesotho and extending southwestwards into the Stormberg and Amathole Mountains. These are some of the highest elevation regions of southern Africa and the topography in these

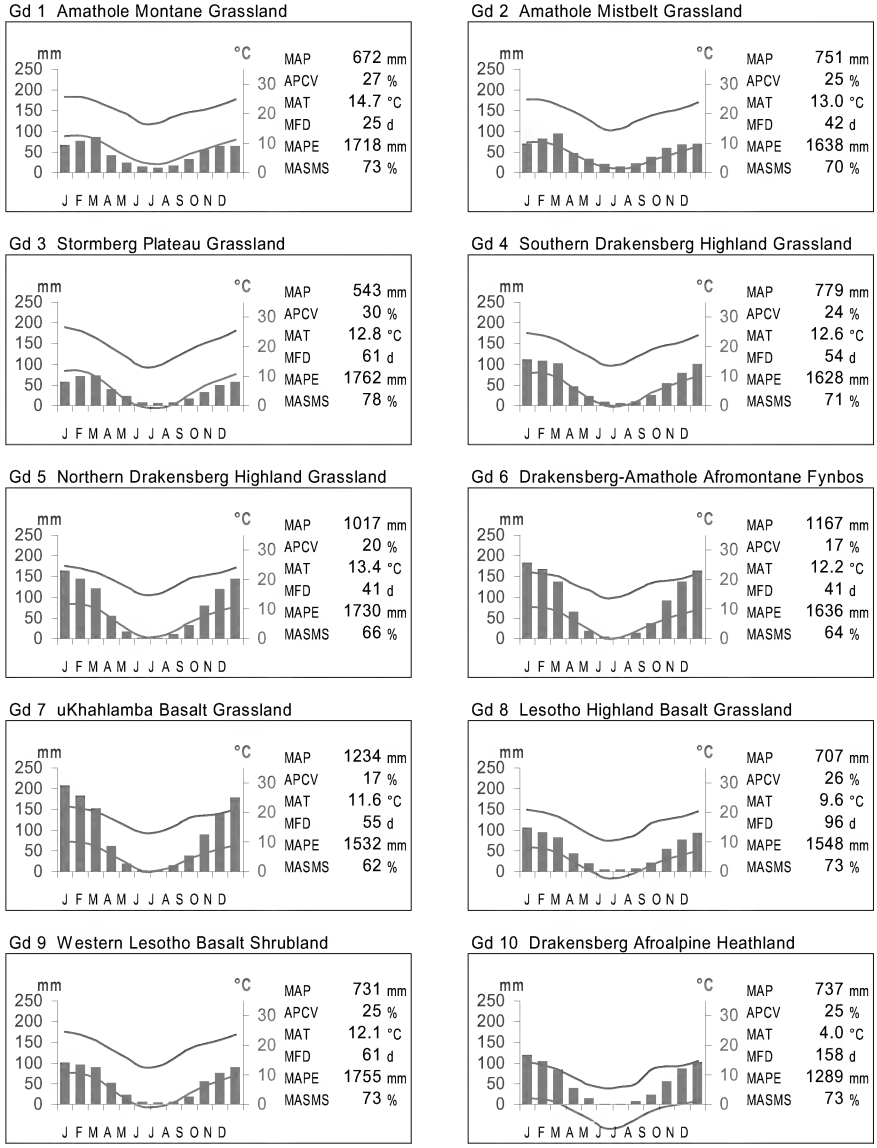

Figure 8.11 Climate diagrams of the Drakensberg Grassland Bioregion units. Blue bars show the median monthly precipitation. The upper and lower red lines show the mean daily maximum and minimum temperature respectively. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days (days when screen temperature was below 0°C); MAPE: Mean Annual Potential Evaporation; MASMS: Mean Annual Soil Moisture Stress (% of days when evaporative demand was more than double the soil moisture supply).

areas may be very steep. The rainfall is generally very high, precipitation may occur at any time of the year and orographic mists supplement rainfall. At the highest elevations snow and frost are common and temperatures are usually cool to cold (Figure 8.11).

Heathlands are found either on steep slopes or in the extreme summit positions such as the highest mountain ridges, edges of flat mesas or damp, high-altitude plateaus. These are found in South Africa from the Soutpansberg to the Amathole, with larger patches occurring on the Lesotho plateau. The substrate in these localities is often leached by continuous precipitation and soils tend to be nutrient-poor. Similar heathlands may be found throughout the East African mountain chains and also in Madagascar and on the Mascarene Islands at similar (or higher) elevations (Hedberg 1951, 1955, 1964, White 1983, Carbutt & Edwards 2001).

Gd 1 Amathole Montane Grassland

VT 44 Highland Sourveld and Dohne Sourveld (73%) (Acocks 1953). LR 42 Moist Upland Grassland (52%) (Low & Rebelo 1996).

Distribution Eastern Cape Province: The main grassland unit of the Amathole, Winterberg and Kologha Mountains as well as the mountains just north of Somerset East (Bosberg and other outlying peaks). Also found on broken veld between Stutterheim and Komga. At altitudes 650–1 500 m.

Vegetation & Landscape Features Low mountain ranges and moderately undulating landscapes characterised by short grassland with high species richness of forbs, especially those of the family Asteraceae (especially *Helichrysum* and *Senecio*). The grasslands are dominated by a variety of grasses, including *Themeda triandra*, *Elionurus muticus*, *Sporobolus africanus*, *Eragrostis chloromelas*, *E. curvula*, *Heteropogon contortus*, *Alloteropsis semialata* and *Tristachya leucothrix*.

Geology & Soils On sedimentary rocks of the Beaufort Group (Karoo Supergroup) overlaid by deep, freely drained, highly weathered soils (Hartmann 1988). Weakly developed lithosols are also found in places. Most common land types Fb, Fa and Fc.

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Figure 8.12 Gd 1 Amathole Montane Grassland: Montane grasslands north of Hogsback (Amathole, Eastern Cape) with Elandsberg in the background; *Themeda triandra* and a species of *Scabiosa* are prominent here.

Climate Bimodal rainfall pattern with spring and late summer peaks. MAP around 670 mm (range 500–740 mm, up to 1 000 mm in isolated places). Rainfall the highest in high-altitude areas due to orographic factors and becoming lower with reduction in elevation and with distance westwards. Coefficient of variation in rainfall decreases with elevation, and ranges from 15–31% across the unit. Overall MAP close to 15°C. Winter frost is not common in the southeastern part of this unit, but it is more frequent (up to 80 days per year) in the western and northwestern regions. See also climate diagram for Gd 1 Amathole Montane Grassland (Figure 8.11).

Important Taxa Graminoids: *Cynodon dactylon* (d), *Eragrostis chloromelas* (d), *E. curvula* (d), *Microchloa caffra* (d), *Themeda triandra* (d), *Tristachya leucothrix* (d), *Agrostis lachnantha*, *Alloteropsis semialata* subsp. *eckloniana*, *Andropogon appendiculatus*, *Brachiaria serrata*, *Cymbopogon pospischilii*, *Cyperus usitatus*, *Elionurus muticus*, *Eragrostis capensis*, *E. plana*, *E. planiculmis*, *E. racemosa*, *Eulalia villosa*, *Harpochloa falx*, *Heteropogon contortus*, *Koeleria capensis*, *Kyllinga alata*, *Melica decumbens*, *Pennisetum sphacelatum*, *Pentaschistis cirrhulosa*, *P. tysonii*, *Schoenoxiphium sparteum*, *Sporobolus africanus*, *Trachypogon spicatus*. Herbs: *Ajuga ophrydis*, *Commelina africana*, *Gerbera piloselloides*, *Haplocarpha scaposa*, *Helichrysum nudifolium* var. *pilosellum*, *H. rugulosum*, *H. simillimum*, *H. umbraculigerum*, *Lepidium africanum* subsp. *africanum*, *Lobelia erinus*, *Rumex lanceolatus*, *Selago densiflora*, *Senecio erubescens* var. *crepidifolius*, *S. retrorsus*, *Tephrosia capensis* var. *acutifolia*, *Tolpis capensis*, *Trifolium burchellianum* subsp. *burchellianum*, *Wahlenbergia stellarioides*. Geophytic Herbs: *Disa tysonii*, *D. versicolor*, *Disperis oxyglossa*, *Eucomis autumnalis* subsp. *autumnalis*, *Geum capense*, *Gladiolus longicollis* subsp. *longicollis*, *Habenaria lithophila*, *Hypoxis argentea* var. *argentea*, *Oxalis smithiana*, *Satyrium cristatum*. Succulent Shrub: *Delosperma crassuloides*. Herbaceous Climber: *Rhynchosia totta*. Low Shrubs: *Anthospermum rigidum* subsp. *pumilum*, *Chrysocoma ciliata*, *Felicia filifolia* subsp. *filifolia*, *F. muricata*, *Helichrysum asperum* var. *albidulum*, *H. odoratissimum*, *H. trilineatum*, *Otholobium caffrum*, *Senecio burchellii*, *S. pterophorus*.

Biogeographically Important Taxa ([D]Drakensberg endemic, [Dg]Drakensberg endemic extending to Griqualand East) Graminoids: *Bromus speciosus*[D], *Helictotrichon galpinii*[D], *Pentaschistis airoides* subsp. *jugorum*[D]. Herbs: *Helichrysum aureum* var. *serotinum*[D], *Psammotropha mucronata* var. *marginata*[D]. Geophytic Herb: *Disa stricta*[Dg].

Endemic Taxa Herbs: *Alchemilla bolusii*, *Alepidea macowani*, *Cineraria vagans*, *Diascia ramosa*, *Helichrysum isolepis*, *Heliophila katbergensis*, *Hermannia violacea*, *Wahlenbergia laxiflora*. Geophytic Herbs: *Aspidoglossum uncinatum*, *Nerine filamentosa*, *Pachycarpus linearis*, *Watsonia amatolae*. Succulent Shrub: *Delosperma katbergense*. Semiparasitic Herb: *Thesium orientale*. Low Shrubs: *Abutilon flanaganii*, *Arrowsmithia styphelioides*, *Erica amatolensis*, *Euryops ciliatus*, *Garuleum tanacetifolium*, *Indigofera cuneifolia* var. *angustifolia*, *Lotononis trichodes*, *Macowania revoluta*, *Muraltia rara*, *Phylica galpinii*, *P. simii*, *Tephrosia polystachya* var. *longidens*.

Conservation Least threatened. Target 27%. Only about 5% conserved in 11 statutory conservation areas (Mpofu Game Reserve, Fort Fordyce, Bosberg, Bush Nek Outspan and Quacu Nature Reserves, Kologha Forest Reserve as well as in Kubusi, Hogsback, Isidenge, Katberg and Cathcart State Forests). Some patches are conserved in at least two private reserves (Bushy Park Natural Heritage Site, Oudekraal Game Farm). More than 10% already transformed for plantations and cultivation. Heavily grazed by cattle and horses (in places), resulting in a uniform, short grassland structure and several prominent indigenous weedy forbs (e.g. *Senecio retrorsus*). The alien invaders include *Acacia mearnsii* and *A. dealbata*. Erosion very low, low or moderate.

Remarks Northern and southern watersheds tend to have distinctive species compositions due to differences in solar insolation levels and moisture regime (Hoare 1997, Hoare & Bredenkamp 1999). Due to this factor, the northern watershed towards the western end of this unit forms a mosaic with and is then gradually replaced by Gh 1 Karoo Escarpment Grassland in the mountains. The Gd 2 Amathole Mistbelt Grassland unit is embedded within this unit at higher altitudes.

References Acocks (1953), Hoare (1997), Hoare & Bredenkamp (1999).

Gd 2 Amathole Mistbelt Grassland

VT 44 Highland Sourveld and Dohne Sourveld (98%) (Acocks 1953). LR 42 Moist Upland Grassland (92%) (Low & Rebelo 1996).

Distribution Eastern Cape Province: On the highest ridges of the Winterberg, Katberg, Amathole and Kologha ranges. Altitude 1 380–2 080 m, most of the area 1 500–1 680 m.

Vegetation & Landscape Features Mountains and moderately undulating slopes below peaks, often with ridges of rock or boulder outcrops. Vegetation is a short grassland dominated by *Themeda triandra*, *Heteropogon contortus*, *Alloteropsis semialata*, *Tristachya leucothrix*, *Festuca caprina* and *F. costata*, with a high diversity of asteraceous herbs, including *Helichrysum appendiculatum*, *H. aureum*, *H. asperum*, *H. simillimum*, *H. odoratissimum*, *H. nudifolium* and *H. anomalum*.

Geology & Soils Deep, freely drained, highly weathered soils overlying the Beaufort Group (predominantly Triassic Tarkastad Subgroup) sedimentary rocks. Dominant land type Fb (two thirds of the region), Ib land type covers about a third.

Climate Bimodal spring-autumn rainfall pattern although rain can fall at any time of the year, and it increases from west to east as well as with increasing elevation. Coefficient of variation in MAP from 15–29% across the unit. MAP 550–1 100 mm (overall regional average 750 mm). Precipitation supplemented by orographically induced precipitation (mist and drizzle). MAT of 13°C indicates a cool-temperate climate. Incidence of frost is 20–95 days (average 42) per year, but the probability of the frost occurrence is higher in the western regions of the unit. See also climate diagram for Gd 2 Amathole Mistbelt Grassland (Figure 8.11).

Important Taxa Graminoids: *Heteropogon contortus* (d), *Themeda triandra* (d), *Alloteropsis semialata* subsp. *eckloniana*, *Andropogon appendiculatus*, *Cymbopogon marginatus*, *Elionurus muticus*, *Eragrostis capensis*, *E. chloromelas*, *E. planiculmis*, *Festuca caprina*, *F. costata*, *Melica decumbens*, *Microchloa caffra*, *Sporobolus africanus*, *Tristachya leucothrix*. Herbs: *Aster bakerianus*, *Cephalaria oblongifolia*, *Helichrysum glomeratum*, *H. mixtum*, *H. nudifolium* var. *pilosellum*, *H. rugulosum*, *H. simillimum*, *Lasiospermum bipinnatum*, *Lobelia erinus*, *L. flaccida*, *Monopsis scabra*, *Selago densiflora*, *Senecio asperulus*, *Trifolium burchellianum* subsp. *burchellianum*. Geophytic Herb: *Moraea reticulata*. Low Shrubs: *Anthospermum paniculatum*, *Chrysocoma ciliata*, *Euphorbia striata*, *Felicia filifolia* subsp. *filifolia*, *Helichrysum anomalum*, *H. asperum* var. *albidulum*, *H. odoratissimum*, *Pentzia cooperi*, *Rubus ludwigii* subsp. *ludwigii*, *Stoebe plumosa*.

Endemic Taxa Herbs: *Galium amatymbicum*, *Nidorella undulata*. Geophytic Herb: *Hypoxis woodii*. Low Shrubs: *Helichrysum montis-cati* (d), *Euryops dyeri*, *Indigofera elandsbergensis*, *Lotononis holosericea*. Succulent Shrubs: *Delosperma alpinum*, *D. dyeri*.

Conservation Least threatened. Target 27%. About 4% conserved in units under governmental management: Hogsback State Forest, Kologha Forest Reserve, Katberg State Forest and Kubusi Indigenous State Forest. About 3% already transformed for plantations. Invasive alien *Acacia dealbata* is a local threat. Erosion very low or low.

Remarks There are some very isolated unmapped patches of Gd 6 Drakensberg-Amathole Afromontane Fynbos embedded within this grassland unit. This vegetation is probably what Acocks (1988) referred to when he remarked on the similarity of grassy fynbos to some parts of the Dohne Sourveld on the summits of the Amathole and Katberg Mountains. The number of *Helichrysum* species in this vegetation is noteworthy—a small plot can share as many as 10 species.

References Story (1952), Acocks (1953, 1988), Killick (1978b), Hoare (1997), Hoare & Bredenkamp (1999).

Gd 3 Stormberg Plateau Grassland

VT 59 Stormberg Plateau Sweet Veld (63%) (Acocks 1953). LR 44 Southeastern Mountain Grassland (76%) (Low & Rebelo 1996).

Distribution Eastern Cape Province: Gently sloping landscapes on the Stormberg Plateau north of Molteno and Dordrecht, east of Burgersdorp and extending northwards not much beyond Jamestown. Altitude 1 520–1 960 m, concentrated between 1 640 m and 1 680 m.

Vegetation & Landscape Features Relatively flat to undulating landscape with hills and mountain peaks jutting above the general landscape. The vegetation is a grassland with a strong dwarf shrub component and, on rocky outcrops, shrubland vegetation may occur. Common and dominant species include *Themeda triandra*, *Eragrostis chloromelas*, *Elionurus muticus*, *Karroochloa purpurea*, *Heteropogon contortus*, *Eragrostis capensis*, *Merxmuellera disticha*, *Helictotrichon turgidulum*, *Felicia filifolia* and *Chrysocoma ciliata*.

Geology & Soils Generally shallow soils (typical of Fb, Da and Db land types), with variable amounts of soil skeleton and overlying mudstones and sandstones of the Elliot Formation and in some areas also of the Molteno Formation (Stormberg Group, Karoo Supergroup).

Climate Variable. The rainfall pattern shows a spring-autumn bimodality with overall MAP 540 mm. There is an east-west rainfall gradient across this vegetation unit from 450 mm in the west to over 700 mm in the east. Coefficient of variation of MAP 30%, varying only slightly from 26–31% across the unit. MAT of nearly 13°C indicates a cool-temperate regime, with climate becoming extremely cold in places. One of the coldest recorded minimum temperatures in South Africa was –18.9°C at Buffelsfontein in the centre of this unit. Frosts can occur at any time of the year, but with a low probability in summer. Incidence of frost from 30–75 days, increasing with

elevation. See also climate diagram for Gd 3 Stormberg Plateau Grassland (Figure 8.11).

Important Taxa Graminoids: *Elionurus muticus* (d), *Eragrostis chloromelas* (d), *Merxmuellera disticha* (d), *Themeda triandra* (d), *Andropogon appendiculatus*, *Aristida diffusa*, *Cynodon incompletus*, *Cyperus usitatus*, *Digitaria eriantha*, *Eragrostis capensis*, *E. curvula*, *E. racemosa*, *Festuca scabra*, *Ficinia gracilis*, *Harpochloa falx*, *Helictotrichon turgidulum*, *Karroochloa purpurea*, *Koeleria capensis*, *Merxmuellera drakensbergensis*, *Microchloa caffra*, *Miscanthus capensis*, *Panicum gilvum*, *Pennisetum sphacelatum*, *Pentaschistis microphylla*, *Schoenoxiphium rufum*, *Tetrachne dregei*, *Tragus koelerioides*, *T. racemosus*. Herbs: *Ajuga ophrydis*, *Galium capense* subsp. *capense*, *Gazania krebsiana* subsp. *krebsiana*, *Gerbera piloselloides*, *Hebenstretia dentata*, *Helichrysum nudifolium* var. *pilosellum*, *H. rugulosum*, *Pseudognaphalium oligandrum*, *Senecio asperulus*, *S. retrorsus*, *Tribulus terrestris*, *Trifolium burchellianum* subsp. *burchellianum*, *Wahlenbergia stellarioides*. Succulent Herb: *Crassula lanceolata*. Low Shrubs: *Chrysocoma ciliata* (d), *Felicia filifolia* subsp. *filifolia*, *F. muricata*, *Gomphocarpus fruticosus* subsp. *fruticosus*, *Helichrysum asperum* var. *albidulum*, *H. dregeanum*, *H. trilineatum*, *Passerina montana*, *Pentzia globosa*, *Selago saxatilis*, *Wahlenbergia albens*. Tall Shrub: *Rhus pyroides*. Woody Climber: *Clematis brachiata*.

Biogeographically Important Taxa ([D]Drakensberg endemic, [Dg]Drakensberg endemic extending to Griqualand East) Graminoid: *Pentaschistis galpinii*[D]. Herbs: *Diascia integerrima*[D], *Psammotropha mucronata* var. *marginata*[D]. Low Shrub: *Relhania acerosa*[Dg]. Tall Shrub: *Lotononis lotononoides*[D].

Endemic Taxon Low Shrub: *Euryops calvescens*.

Conservation Least threatened. Target 27%. None conserved in statutory conservation areas. About 9% transformed, mostly for cultivation. Erosion moderate, high and low.

Remarks The region of this unit forms a transitional zone between the Gh 1 Karoo Escarpment Grassland to the west and the Gd 4 Southern Drakensberg Highland Grassland towards the higher altitudes in the east. Floristic elements typical of both neighbouring regions meet here. Outcrops of the Drakensberg and Stormberg Groups (Karoo Supergroup) and pyroclastic rocks within this unit support vegetation resembling that of the Gd 4 Southern Drakensberg Highland Grassland. On the other hand, rocky, dry aspects in the gently sloping landscapes tend to have more karoo elements. Within the Stormberg Plateau Grassland unit, the vegetation patterns are strongly influenced by moisture gradients (Hoare & Bredenkamp 2001). The bottomlands at the foot of the hills consist mostly of flat, wide, unchannelled drainage valleys containing dense hygrophilous grasslands dominated by species such as *Pennisetum sphacelatum*.

References Acocks (1953, 1988), Hoare & Bredenkamp (2001).

Gd 4 Southern Drakensberg Highland Grassland

VT 44 Highland Sourveld and Dohne Sourveld (40%), VT 58 *Themeda–Festuca* Alpine Veld (32%) (Acocks 1953). LR 44 South-eastern Mountain Grassland (36%), LR 42 Moist Upland Grassland (27%) (Low & Rebelo 1996). BRG 10 Montane Veld (Camp 1999b).

Distribution Eastern Cape and KwaZulu-Natal Provinces: An intricate system of patches and corridors across the highest mountains and ridges of the Stormberg, from Molteno to the surrounds of Dordrecht, also including the elevated broad valley of the Kraairivier (near Barkly East) and its tributaries. Further occurring in a broad band (and abutting onto Gd 8 Lesotho Highland Basalt Grassland at upper boundary) on steep slopes of head-valleys fringing the edge of the southern Drakensberg Escarpment covering the regions north and northwest of Indwe, Elliot, Ugie, Maclear, Mt Fletcher (all Eastern Cape) as far as Matatiele (KwaZulu-Natal). From about the Ramatseliso Nek (pass) north of Matatiele the upper boundary of this unit is formed by the Gd 7 uKhahlamba Basalt Grassland—from here the Gd 4 Southern Drakensberg Highland Grassland follows a system of high northwest-southeast-tending ridges as far north as the southeastern extension of the Giant's Castle buttress (KwaThabamnyana). Altitude 1 420–2 080 m, mainly between 1 720–1 840 m.

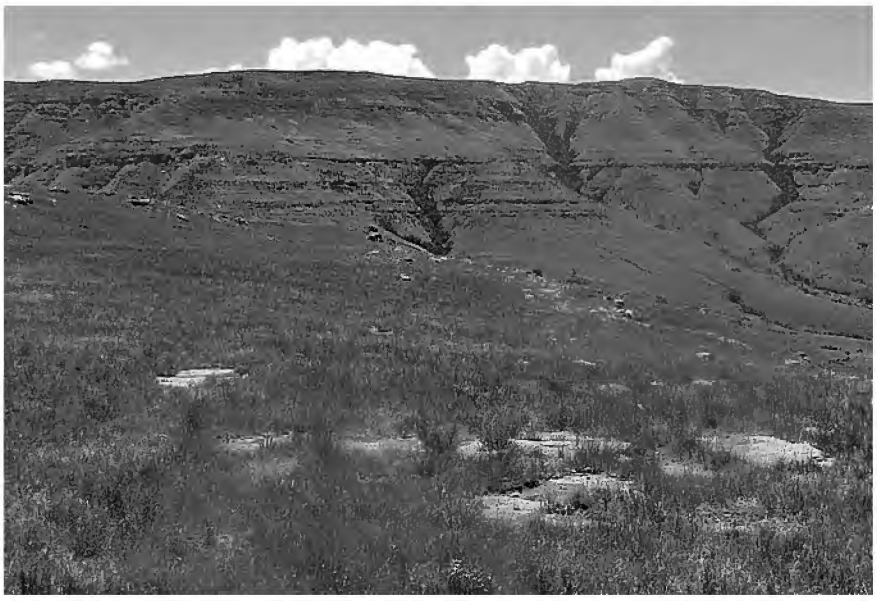
Vegetation & Landscape Features Steeply sloping mountainous areas on and below the summit of the Great Escarpment supporting dense tussock grassland on slopes sometimes with a dwarf-shrubby component and dwarf shrubland on exposed rocky areas. The tussock grassland is dominated by various species of *Festuca* and other grasses such as *Themeda triandra*, *Heteropogon contortus*, *Eragrostis racemosa*, *Eragrostis chloromelas*, *E. curvula*, *Elionurus muticus*, *Trachypogon spicatus*, *Andropogon appendiculatus*, *Harpochloa falx* and *Tristachya leucothrix*.

D.B. Hoare

Figure 8.13 Gd 3 Stormberg Plateau Grassland: Grasslands with prominent *Themeda triandra*, *Eragrostis chloromelas*, *Cymbopogon pospischilii*, *Eragrostis gummiflua*, *Elionurus muticus*, north of Jamestown (Eastern Cape).

Geology & Soils Sandstones of the Clarens Formation and sandstones, siltstones and mudstones of the Elliot Formation (both formations belonging to the Stormberg Group, Karoo Supergroup) as well as the basaltic lava flows of the Drakensberg Group. Soils on the steep escarpment slopes tend to be deep and fine-grained, typical of land types Fa, Fb and Ea.

Climate Summer rainfall, with very dry winters. MAP 780 mm (500–1 120 mm), increasing from west to east to close to the southern border of Lesotho.



M.C. Rutherford

Figure 8.14 Gd 4 Southern Drakensberg Highland Grassland: High-altitude grasslands on the Pitseng Pass between Mount Fletcher and Naudesnek (Eastern Cape) with patches of unmapped FOz 3 Southern Mistbelt Forest in the ravines.

Northeast of the latter region MAP increases with increasing elevation. The coefficient of variation of MAP 16–31% across the unit, with the highest values in the region around the Stormberg Plateau. Temperature regime cool-temperate (MAT around 13°C), typically montane, with cool day-time temperatures throughout the year and the potential for cold conditions at any time. Winter frost is common (30–90 days, average 54 days), incidence increasing with elevation. The areas of high altitude regularly receive snow in winter, sometimes in considerable quantities as a result of clashes of water-laden eastbound fronts with high-altitude cold air masses. See also climate diagram for Gd 4 Southern Drakensberg Highland Grassland (Figure 8.11).

Important Taxa Graminoids: *Alloteropsis semialata* subsp. *eckloniana* (d), *Aristida junciformis* subsp. *galpinii* (d), *Catalepis gracilis* (d), *Diheteropogon filifolius* (d), *Eragrostis caesia* (d), *E. chloromelas* (d), *E. planiculmis* (d), *E. racemosa* (d), *Festuca caprina* (d), *Microchloa caffra* (d), *Monocymbium ceresiiforme* (d), *Pennisetum sphacelatum* (d), *Rendlia altera* (d), *Themeda triandra* (d), *Trachypogon spicatus* (d), *Tristachya leucothrix* (d), *Agrostis lachnantha*, *Andropogon appendiculatus*, *Aristida diffusa*, *Cymbopogon pospischilii*, *Elionurus muticus*, *Eragrostis capensis*, *E. curvula*, *E. plana*, *Festuca scabra*, *Fingerhuthia sesleriiformis*, *Harpochloa falx*, *Helictotrichon turgidulum*, *Heteropogon contortus*, *Juncus exsertus* subsp. *exsertus*, *Koeleria capensis*, *Pentaschistis cirrhulosa*, *P. microphylla*, *Poa binata*, *Schoenoxiphium sparteum*, *Sporobolus centrifugus*. Herbs: *Ajuga ophrydis*, *Aster bakerianus*, *Euphorbia epicyparissias*, *Galium capense* subsp. *capense*, *Gazania krebsiana* subsp. *krebsiana*, *Haplocarpha scaposa*, *Hebenstretia dentata*, *Helichrysum chionosphaerum*, *H. nudifolium* var. *piloselloides*, *H. rugulosum*, *H. umbraculigerum*, *Kohautia amatymbica*, *Lactuca inermis*, *Lasiospermum bipinnatum*, *Lobelia erinus*, *L. flaccida*, *L. vanreenensis*, *Pentanisia prunelloides* subsp. *latifolia*, *Psammotropha mucronata* var. *foliosa*, *Rumex lanceolatus*, *Salvia stenophylla*, *Selago densiflora*, *S. galpinii*, *Senecio asperulus*, *S. erubescens* var. *crepidifolius*, *Tolpis capensis*, *Trifolium burchellianum* subsp. *burchellianum*, *Wahlenbergia cuspidata*, *W. stellarioides*. Geophytic Herbs: *Cheilanthes hirta*, *Corycium dracomontanum*, *Disa fragrans* subsp. *fragrans*, *Disperis oxyglossa*, *Drimia macrocentra*, *Eriospermum ornithogaloides*, *Geum capense*, *Hypoxis rigidula* var. *pilosissima*. Herbaceous Climber: *Rhynchosia totta*. Low Shrubs: *Chrysocoma ciliata*, *Erica caffrorum* var. *caffrorum*, *Euryops candollei*, *Felicia filifolia* subsp. *filifolia*, *F. muricata*, *Helichrysum asperum* var. *albidulum*, *H. splendidum*, *H. trilineatum*, *Passerina montivagus*, *Pentzia cooperi*, *Rubus ludwigii* subsp. *ludwigii*, *Selago albida*, *S. saxatilis*, *Senecio burchellii*.

Biogeographically Important Taxa ([D]Drakensberg endemic, [Dg]Drakensberg endemic extending to Griqualand East) Graminoids: *Pentaschistis airoides* subsp. *jugorum*[D], *Polevansia rigida*[D], *Restio galpinii*[Dg]. Herbs: *Aster ananthocladus*[D], *Berkheya multijuga*[D], *Diascia integerrima*[D], *Wahlenbergia polytrichifolia* subsp. *dracomontana*[D]. Geophytic Herbs: *Corycium alticola*[D], *Merwilla dracomontana*[D], *Rhodohypoxis rubella*[D], *Schizochilus bulbinella*[Dg]. Low Shrubs: *Erica aestiva* var. *aestiva*[D], *E. algida*[Dg], *E. dominans*[D], *E. dracomontana*[D], *E. frigida*[D], *E. schlechterii*[D], *E. wyliei*[D], *Helichrysum glaciale*[D], *H. marginatum*[D], *Relhania acerosa*[Dg]. Tall Shrub: *Lotononis lotononoides*[D].

Endemic Taxa Graminoid: *Festuca vulpioides*. Herbs: *Alepidea insculpta*, *Aster confertifolius*, *Diascia megathura*, *Felicia caespitosa*, *Helichrysum longinquum*, *Osteospermum attenuatum*, *Selago leptothrix*, *Wahlenbergia appressifolia*. Geophytic Herbs: *Aspidonepsis cognata*, *Disa nivea*, *Trachyandra smalliana*. Low Shrubs: *Erica anomala*, *E. caffrorum* var. *glomerata*, *E. hillburttii*, *Lotononis jacottetii*, *L. minor*.

Conservation Least threatened. Target 27%. Almost 9% statutorily conserved in uKhahlamba Drakensberg Park and Malekgonyane (Ongeluksnek) Wildlife Reserve. More than 5% already transformed for cultivation. Alien invader *Acacia dealbata* occurs scattered in places. Erosion mainly very low (57%), to lesser extent low or moderate (13%).

Remark Unmapped patches of AZf 4 Drakensberg Wetlands are abundant in seepage areas (dominated by *Merxmuellera drakensbergensis*) and in drainage valleys, typically with the tall shrub *Leucosidea sericea* dominant.

References Acocks (1953, 1988), Bester (1998), Camp (1999b), Hoare & Bredenkamp (2001).

Gd 5 Northern Drakensberg Highland Grassland

VT 44 Highland Sourveld and Dohne Sourveld (81%) (Acocks 1953). LR 41 Wet Cold Highveld Grassland (51%) (Low & Rebelo 1996). BRG 10 Montane Veld (55%) (Camp 1999b).

Distribution KwaZulu-Natal and Free State Provinces: Northeastern and eastern slopes of valleys and buttresses of the Drakensberg in KwaZulu-Natal where most of the region is locally known as Little Berg, from Giant's Castle to slopes in any direction in the surrounds of Clarens in the Free State. Altitude 1 460–2 060 m, mostly 1 780–1 840 m.

Vegetation & Landscape Features Mountainous region characterised by steep slopes of broad valleys and supporting mainly short, sour grasslands, rich in forbs. So-called '*Protea*

L. Mucina

Figure 8.15 Gd 5 Northern Drakensberg Highland Grassland: Sandstone cliffs with *Leucosidea sericea* shrubland in a belt of *Protea subvestita* in the Golden Gate Highlands National Park near Clarens (Free State).

savannas'—grasslands that contain widely scattered trees of *Protea caffra* and occasionally *P. roupelliae*—fall within this unit. Sandstone cliffs, a major characteristic of this landscape, create a multitude of special habitats (often fire-protected) for many special plant communities.

Geology & Soils Mudstone and sandstone of the Elliot Formation and sandstone of the Clarens Formation (Stormberg Group, Karoo Supergroup) supporting soils typical of the Fc land type (dominant) as well as Ac and Bb land types (of lesser importance).

Climate Summer-rainfall region, with MAP broadly ranging from 720–1 630 mm (overall average MAP 1 017 mm). Snowfalls are occasional and last several days. Summer mists frequent. Hot dry winds frequent from July to October. Summers warm and winters cold, with frequent considerably severe frost events. Overall regional MAT 13.4°C. See also climate diagram for Gd 5 Northern Drakensberg Highland Grassland (Figure 8.11).

Important Taxa Graminoids: *Setaria sphacelata* (d), *Themeda triandra* (d), *Agrostis lachnantha*, *Andropogon schirensis*, *Aristida adscensionis*, *A. bipartita*, *A. diffusa*, *A. junciformis* subsp. *galpinii*, *Brachiaria eruciformis*, *B. serrata*, *Bulbostylis densa* subsp. *densa*, *B. humilis*, *Catalepis gracilis*, *Digitaria flaccida*, *D. monodactyla*, *D. ternata*, *Diheteropogon filifolius*, *Elionurus muticus*, *Eragrostis capensis*, *E. chloromelas*, *E. gummiflua*, *E. plana*, *E. racemosa*, *E. sclerantha*, *Harpochloa falx*, *Heteropogon contortus*, *Hyparrhenia dregeana*, *H. hirta*, *Kyllinga melanosperma*, *K. pauciflora*, *Melinis nerviglumis*, *Microchloa caffra*, *Monocymbium ceresiiforme*, *Panicum natalense*, *Pennisetum sphacelatum*, *Setaria nigrirostris*, *Stipagrostis zeyheri* subsp. *sericans*, *Trachypogon spicatus*, *Trichoneura grandiglumis*, *Tristachya leucothrix*. Herbs: *Ajuga ophrydis*, *Berkheya discolor*, *Cineraria lyratiformis*, *Conyza podocephala*, *Helichrysum adenocarpum*, *H. chionosphaerum*, *H. glomeratum*, *H. rugulosum*, *Hermannia depressa*, *Hibiscus aethiopicus* var. *ovatus*, *Indigastrum fastigiatum*, *Monopsis decipiens*, *Salvia repens* var. *keiensis*, *S. stenophylla*, *Senecio erubescens* var. *crepidifolius*, *S. latifolius*. Geophytic Herbs: *Disa versicolor*, *Eucomis autumnalis* subsp. *autumnalis*, *E. bicolor*, *Pteridium aquilinum*. Low Shrubs: *Anthospermum rigidum* subsp. *pumilum*, *Clutia affinis*, *Erica drakensbergensis*, *Felicia muricata*, *Gnidia kraussiana*, *Helichrysum hypoleucum*, *Protea dracomontana*, *P. simplex*, *Wahlenbergia dieterlenii*. Succulent Shrub: *Crassula dependens*. Small Trees: *Protea caffra* subsp. *caffra* (d), *P. roupelliae* subsp. *roupelliae* (d), *P. subvestita* (d).

Biogeographically Important Taxa ([D]Drakensberg endemic, [Dg]Drakensberg endemic extending to Griqualand East) Herbs: *Alepidea pilifera*[D], *Chironia peglerae*[D]. Geophytic Herbs: *Asclepias oreophila*[D], *Elaphoglossum drakensbergense*[D], *Eucomis schijffii*[D], *Galtonia regalis*[D], *Merwilla dracomontana*[D], *Ornithogalum diphyllum*[Dg]. Low Shrubs: *Erica ebracteata*[D] (d), *E. aestiva* var. *aestiva*[D], *E. algida*[Dg].

Endemic Taxa Geophytic Herbs: *Gladiolus loteniensis*, *Hesperantha scopulosa*.

Conservation Least threatened. Target 27%. Some 38% statutorily conserved in the uKhahlamba Drakensberg Park, Sterkfontein Dam Nature Reserve, Golden Gate Highlands National Park, Qwaqwa National Park and Poccolan Nature Reserve. About 7% already transformed by cultivation, urban sprawl or by the building of dams. Alien plant invasions are generally localised, but can be severe. Some important problem species include: *Acacia dealbata*, *A. mearnsii*, *Hypericum perforatum*, *Pinus patula*, *Populus canescens*, *Pyracantha angustifo-*

P.J. du Preez

Figure 8.16 Gd 5 Northern Drakensberg Highland Grassland: Species-rich moist grassland on sandstone with scattered *Protea caffra* at Cathkin Peak, Drakensberg (KwaZulu-Natal).

lia, *P. crenulata*, *Robinia pseudoacacia*, *Rubus cuneifolius* and *Salix fragilis*. Erosion very low (72%) or low (25%).

References Acocks (1953, 1988), Killick (1963), Edwards (1967), Du Preez & Bredenkamp (1991), Hill (1996), Camp (1999b).

Gd 6 Drakensberg-Amathole Afromontane Fynbos

VT 44 Highland Sourveld and Dohne Sourveld (57%) (Acocks 1953). LR 46 Alti Mountain Grassland (41%), LR 41 Wet Cold Highveld Grassland (21%) (Low & Rebelo 1996). BRG 10 Montane Veld p.p. (Camp 1999b). Subalpine Fynbos & Subalpine Heath (Killick 1978a). Including *Cymbopogon–Passerina* Macchia (Roberts 1966).

Distribution KwaZulu-Natal, Eastern Cape and Free State Provinces (presumably also in Lesotho): Series of isolated patches in deeply incised Drakensberg valleys (both in the Northern and Southern Berg) with the southernmost outliers on the Amathole Mountains (Eastern Cape) as well as odd outliers deep into KwaZulu-Natal at high altitude (e.g. Madlozi Mountain) north of Qudeni in the Nkandla District. Most patches found at altitudes around 1 660 m, and then from 1 900–2 060 m, with notable outliers situated as low as 1 520 m and as high as 2 600 m.

Vegetation & Landscape Features Steep valleys and escarpment slopes at the head of rivers with small stands in stream gullies and depressions. Evergreen shrublands 1–3 m tall, many shrubs with ericoid leaves. The most prominent shrubland elements comprise genera such as *Passerina*, *Cliffortia*, *Erica*, *Euryops*, *Helichrysum*, *Macowania*, *Protea*, *Widdringtonia* and *Ischyrolepis*.

Geology & Soils Jurassic basalts (Drakensberg Group) and a variety of Karoo Supergroup sedimentary rocks (mainly sandstone of the Clarens Formation of the Stormberg Group) giving rise to soils of varying depth and nutrient status. Dominant land type Ac, followed by Fa and Ad.

Climate Summer-rainfall region, with MAP 800–1 820 mm (overall regional MAP 1 167 mm). Snowfalls are occasional and summer mists occur frequently. Overall regional MAT of 12.2°C might be misleading since summer days can be quite hot and frost occurs frequently in winter (more than 40 days) and the sheltered position of the afromontane fynbos habitats (steep slopes), often out of direct sun, probably has a profound influence on local microclimate. Hot, dry winds are common from July to October. See also climate diagram for Gd 6 Drakensberg-Amathole Afromontane Fynbos (Figure 8.11).

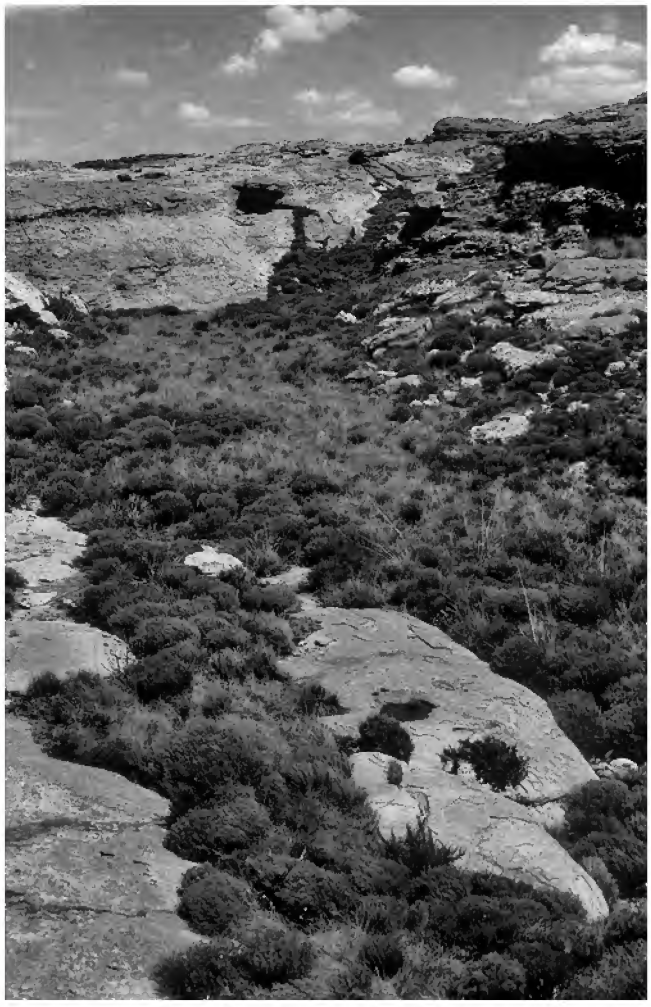
Important Taxa Small Trees: *Widdringtonia nodiflora* (d), *Encephalartos ghellinckii*, *Protea lacticolor*, *P. subvestita*. Low Shrubs: *Passerina montana* (d), *Cliffortia linearifolia*, *C. nitidula*, *C. paucistaminea*, *Clutia natalensis*, *Erica caffrorum* var. *caffrorum*, *E. cerinthoides*, *E. evansii*, *Gymnopentzia bifurcata*, *Otholobium caffrum*, *Protea dracomontana*, *Rhus discolor*, *Stoebe plumosa*. Graminoids: *Aristida junciformis* subsp. *galpinii*, *Cymbopogon nardus*, *Ischyrolepis schoenoides*. Herb: *Helichrysum cooperi*.

Biogeographically Important Taxa ([D]Drakensberg endemic, [Dg]Drakensberg endemic extending to Griqualand East) Tall Shrub: *Lotononis lotononoides*[D] (d). Low Shrubs: *Erica ebracteata*[D] (d), *E. algida*[Dg], *E. dissimulans*[D], *E. frigida*[D], *Euryops tysonii*[D], *Helichrysum albirosulatum*[D].

Endemic Taxa Tall Shrubs: *Melianthus villosus*, *Polemannia montana*. Low Shrubs: *Cliffortia spathulata* (d), *Helichrysum argyrophyllum* (d), *Erica brownleeae*, *E. westii*, *Helichrysum setosum*, *H. tenax*, *H. tenuifolium*, *Macowania conferta*, *Phylica thodei*, *Senecio haygarthii*. Herbs: *Berkheya macrocephala*, *Selago longipedicellata*.

Conservation Target 27%. Least threatened due to poor accessibility and formal protection (more than 50% of the mapped area) in conservation areas such as the uKhahlamba Drakensberg Park (KwaZulu-Natal), Tšehlanyane National Park (Lesotho), Golden Gate Highlands National Park and Qwaqwa National Park (Free State). Those patches that occur some distance away from the Drakensberg Escarpment are threatened by increased fire frequencies.

Remarks Two structurally similar, but floristically very different afromontane fynbos (or fynbos-like) shrublands can be recognised in the Drakensberg and broader surrounds. These two subunits are also differentiated in terms of altitude and the grasslands within which they are embedded. A low-altitude (and relatively species-poor) fynbos-like shrubland with *Passerina montana* is still found on edges of some high eastern Free State tafelbergs, such as Thaba 'Nchu (Roberts 1961), and Korannaberg (Du Preez 1992) as well as at the foot of Clarens sandstone cliffs in the Golden Gate Highlands National Park. *P. montana* also dominates extensive areas of Gd 8 Lesotho Highland Basalt Grassland in Lesotho (see description below) The patches in the Nkandla District are embedded within the Midlands Mistbelt Grassland and we hypothesise that they are evidence of an earlier larger extent that these 'fynbos-like' shrublands might have experienced in some wetter Plio-Pleistocene



P.J. du Preez

Figure 8.17 Gd 6 Drakensberg-Amathole Afromontane Fynbos: Shrubland on Korannaberg (eastern Free State) dominated by *Passerina montana* and accompanied by species of the genera *Cliffortia, Metalasia, Erica, Muraltia, Selago* and *Anthospermum*.

periods. The high-altitude fynbos is a unit with clear afromontane links (*sensu* White 1978) and is limited to Killick's (1963) 'subalpine belt'. Terms such as 'Subalpine Fynbos', 'Subalpine Heath' and '*Passerina–Philippia–Widdringtonia* Fynbos' were coined to designate this unit. Killick (1963), following the then in vogue Clementsian doctrine, considered this fynbos to be the climax of his 'subalpine belt'—an assertion which we do not share.

This vegetation unit is one of the most endemic-rich in the Drakensberg Alpine Centre of Regional Endemism (as defined by Van Wyk & Smith 2001).

Hundreds of small patches of this unique fynbos have not yet been mapped (especially in the Drakensberg and even more so in the Amathole Mountains where none have yet been mapped) due to lack of formal data. In the Amathole Mountains some sites can be regarded as azonal (afromontane) fynbos and contain, among others, *Protea subvestita*, *Erica peltata* and *Cliffortia paucistaminea* (Hoare 1997, Hoare & Bredenkamp 1999). Similar azonal fynbos, including species of *Cliffortia*, *Erica*, *Protea*, *Restio* and others may be found on the slopes of Gaika's Kop near Hogsback. Previous studies have indicated that in the absence of fire and management, mountain grasslands in this area change to a *Cliffortia–Erica*-dominated, fynbos-type vegetation (Story 1952).

References Story (1952), Acocks (1953, 1988), Roberts (1961, 1966), Killick (1963, 1978a, b, 1994), Edwards (1967), Trollope & Booysen (1971), Trollope (1973), Downing et al. (1978), Potgieter (1982), Killick (1990), Du Preez & Bredenkamp (1991), Du Preez (1992), Hill (1996), Hoare (1997), Hoare & Bredenkamp (1999), Van Wyk & Smith (2001).

Gd 7 uKhahlamba Basalt Grassland

VT 58 *Themeda–Festuca* Alpine Veld (54%) (Acocks 1953). LR 46 Alti Mountain Grassland (65%) (Low & Rebelo 1996). BRG 10 Montane Veld p.p. (Camp 1999b).

Distribution KwaZulu-Natal and to a small extent also the Free State and Eastern Cape Provinces and very slightly in Lesotho: Uppermost slopes of the Drakensberg Mountains just below the edge of the highland plateau. Altitude 1 820–3 300 m.

Vegetation & Landscape Features Species-rich grasslands of varying levels of density, forming girlands (terraced tussocks) due to steepness of slopes. Comprising a series of communities dominated by *Bromus speciosus*, *Pentaschistis tysoniana*, *Cymbopogon nardus*, *Festuca caprina*, *Rendlia altera* and *Themeda triandra* that are accompanied by numerous (and in places dominant) herbs (*Agapanthus*, *Merwilla*, *Helichrysum*) and shrubs (*Erica*, *Helichrysum*, *Euryops*). Deep gullies on basalt support luxuriant tall-herb vegetation. Steep basalt rock faces and terraces (the most imposing array of cliffs in southern Africa) are the most dramatic landscape element characteristic of the uKhahlamba (The Barrier of Spears).

Geology & Soils Jurassic Basalts of the Drakensberg Group (Karoo Supergroup)—a result of prolonged volcanic activity accompanying the birth of the African continent by breaking from Gondwana. Deep nutrient-rich soils are formed on less steep slopes, while basalt outcrops usually do not carry any fine soil, except for shallow pockets of basalt rubble. Dominant land type Fa, followed by Ac and Ic.

Climate Summer rainfall, with MAP 830–1 820 mm (overall regional MAP 1 234 mm). Great temperature differences between summer (some days with temperature exceeding 30°C) and winter, characterised by occurrence of snow (does not persist for long on steep exposed slopes) and frequent frost (55 days per year). Morning summer mists are also frequent, but so are hot, dry winds from July to October. Depending on altitude and aspect, the climate characteristics vary considerably. See also climate diagram for Gd 7 uKhahlamba Basalt Grassland (Figure 8.11).

Important Taxa Graminoids: *Cymbopogon nardus* (d), *Eragrostis caesia* (d), *E. curvula* (d), *Festuca costata* (d), *Harpochloa falx* (d), *Heteropogon contortus* (d), *Merxmuellera disticha* (d), *M. stricta* (d), *Monocymbium ceresiiforme* (d), *Pentaschistis tysonii* (d), *Rendlia altera* (d), *Themeda triandra* (d), *Trachypogon spicatus* (d), *Tristachya leucothrix* (d), *Agrostis barbuligera*, *Alloteropsis semialata* subsp. *eckloniana*, *Andropogon appendiculatus*, *Aristida junciformis* subsp. *galpinii*, *A. monticola*, *Brachypodium bolusii*, *Bulbostylis humilis*, *B. schoenoides*, *Carex glomerabilis*, *Cymbopogon marginatus*, *Cyperus schlechteri*, *Digitaria flaccida*, *D. ternata*, *Diheteropogon filifolius*, *Elionurus muticus*, *Eragrostis capensis*, *Festuca scabra*, *Ficinia stolonifera*, *Koeleria capensis*, *Loudetia simplex*, *Merxmuellera stereophylla*, *Panicum ecklonii*, *Pentaschistis aurea* subsp. *pilosogluma*, *P. cirrhulosa*, *P. natalensis*, *Poa binata*, *Scirpus falsus*, *Stiburus alopecuroides*, *Styppeiochloa gynoglossa*, *Tetraria cuspidata*. Herbs: *Cycnium racemosum* (d), *Xerophyta viscosa* (d), *Aster bakerianus*, *Berkheya discolor*, *B. rhapontica* subsp. *rhapontica*, *Craterocapsa tarsodes*, *Cyphia elata*, *Galium capense* subsp. *capense*, *Gnaphalium griquense*, *Helichrysum adenocarpum*, *H. aureonitens*, *H. aureum* var. *monocephalum*, *H. ecklonis*, *H. hyphocephalum*, *H. nanum*, *H. rugulosum*, *H. setigerum*, *H. spiralepis*, *H. subglomeratum*, *H. umbraculigerum*, *Lobelia vanreenensis*, *Protea dracomontana*, *Psammotropha alternifolia*, *P. obovata*, *Sebaea sedoides* var. *confertiflora*, *Senecio arabidifolius*, *S. asperulus*, *Sutera neglecta*, *Wahlenbergia and-*

L. Mucina

Figure 8.18 Gd 7 uKhahlamba Basalt Grassland: Dramatic montane landscape of basalt slopes and peaks of the northern Drakensberg supporting the northernmost occurrence of the high-altitude, species-rich basalt grassland below the Sentinel (Qwaqwa region, close to the meeting point of three political regions: KwaZulu-Natal, the Free State and the Kingdom of Lesotho).

rosacea, *W. undulata*, *Zaluzianskya microsiphon*. Geophytic Herbs: *Agapanthus campanulatus* (d), *Brunsvigia natalensis* (d), *Corycium nigrescens* (d), *Eucomis autumnalis* subsp. *clavata* (d), *Nerine bowdenii* (d), *Albuca shawii*, *Brownleea galpinii*, *Chlorophytum acutum*, *Corycium dracomontanum*, *Dipcadi gracillimum*, *Disa fragrans* subsp. *fragrans*, *D. sankeyi*, *D. versicolor*, *Disperis oxyglossa*, *D. renibractea*, *Drimia macrocentra*, *Eriospermum ornithogaloides*, *Eucomis bicolor*, *Gladiolus dalenii*, *G. ecklonii*, *G. longicollis* subsp. *longicollis*, *Habenaria lithophila*, *Haemanthus humilis* subsp. *hirsutus*, *Hesperantha baurii*, *Holothrix thodei*, *Huttonaea oreophila*, *Hypoxis multiceps*, *Kniphofia ritualis*, *K. triangularis*, *Moraea modesta*, *M. robusta*, *Neobolusia tysonii*, *Oxalis depressa*, *Pachycarpus vexillaris*, *Pterygodium cooperi*, *P. hastatum*, *Rhodohypoxis baurii* var. *baurii*, *Satyrium cristatum*, *S. longicauda*, *S. microrrhynchum*, *Schizochilus flexuosus*, *Tulbaghia leucantha*, *Watsonia gladioloides*, *W. lepida*, *Xysmalobium prunelloides*. Semiparasitic Herb: *Thesium durum*. Low Shrubs: *Helichrysum sutherlandii* (d), *Anthospermum hispidulum*, *Chrysocoma ciliata*, *Dichilus strictus*, *Erica caespitosa*, *E. glaphyra*, *E. woodii*, *Eriocephalus eximius*, *Euryops pedunculatus*, *Gnidia gymnostachya*, *Helichrysum swynnertonii*, *Pelargonium sidoides*. Succulent Shrubs: *Aloe pratensis*, *Crassula sarcocaulis*, *C. tetragona* subsp. *acutifolia*.

Biogeographically Important Taxa ([D]Drakensberg endemic, [Dg]Drakensberg endemic extending to Griqualand East) Graminoids: *Bromus speciosus*[D] (d), *Carex monotropa*[D], *Helictotrichon galpinii*[D], *Pentaschistis exserta*[D], *P. galpinii*[D], *Restio galpinii*[Dg]. Herbs: *Berkheya multijuga*[D] (d), *Alchemilla colura*[Dg], *Aster ananthocladus*[D], *Berkheya pannosa*[Dg], *Cephalaria galpiniana* subsp. *simplicior*[D], *Chironia peglerae*[D], *Cotula linearilloba*[D], *Diascia anastrepta*[D], *D. vigilis*[D], *Felicia linearis*[Dg], *Glumicalyx flanaganii*[D], *Helichrysum albirosulatum*[D], *H. album*[D], *H. argentissimum*[Dg], *H. aureum* var. *scopulosum*[Dg], *H. aureum* var. *serotinum*[D], *H. basalticum*[D], *H. bellum*[D], *H. subfalcatum*[D], *Psammotropha mucronata* var. *marginata*[D], *Senecio tugelensis*[D]. Geophytic Herbs: *Galtonia regalis*[D] (d), *Asclepias oreophila*[D], *Cyrtanthus flanaganii*[D], *Dierama tysonii*[Dg], *Disa cephalotes* subsp. *frigida*[D], *D. oreophila* subsp. *erecta*[D], *D. stricta*[Dg], *D. thodei*[D], *Elaphoglossum drakensbergense*[D], *Eucomis schijffii*[D], *Gladiolus microcarpus*[D], *Hesperantha schelpeana*[D], *Huttonaea grandiflora*[D], *H. woodii*[Dg], *Miraglossum superbum*[D], *Moraea alticola*[D], *Saniella verna* (generic link to Hantam-Roggeveld CE), *Schizochilus angustifolius*[D], *Schizoglossum montanum*[D], *Tulbaghia montana*[D]. Herbaceous Climber: *Cyphia tysonii*[D]. Low Shrubs: *Berkheya rosulata*[D], *Comborhiza virgata*[D], *Erica flanaganii*[D], *E. straussiana*[D], *E. thodei*[Dg], *E. wyliei*[D], *Euryops decumbens*[D], *E. evansii* subsp. *evansii*[D], *E. montanus*[D], *Gnidia compacta*[D], *Helichrysum glaciale*[D], *H. milfordiae*[D], *H. sessilioides*[D], *H. witbergense*[D], *Passerina drakensbergensis*[D].

Endemic Taxa ([N]Northern Berg and [S]Southern Berg only, respectively) Graminoids: *Merxmuellera aureocephala*. Herbs: *Aplanodes doidgeana*, *Berkheya draco*[N], *B. leucaugeta*[N], *Diascia austromontana*, *D. purpurea*, *D. tugelensis*, *Dracosciadium saniculifolium*[N], *Geranium drakensbergensis*[S], *Gerbera parva*, *H. amplectens*[N], *H. evansii*[N], *H. heterolasium*, *H. mollifolium*, *Heliophila formosa*[S], *Hermannia malvifolia*, *Indigofera pseudoevansii*, *Melpomene flabelliformis*, *Nemesia glabriuscula*, *Pimpinella krookii*, *Satureja compacta*, *S. grandibracteata*, *Sebaea radiata*, *Selago trauseldii*, *Senecio basalticus*[N], *S. brevilorus*, *S. cristimontanus*, *S. dissimulans*, *S. mauricei*[S], *S. parentalis*, *S. polelensis*[S], *S. praeteritus*, *S. qathlambanus*, *S. saniensis*[N], *S. telmateius*, *S. thamathuensis*[N], *Wahlenbergia pulvillus-gigantis*[N], *W. tetramera*[N], *Xerophyta longicaulis*, *Xysmalobium woodii*. Geophytic Herbs: *Albuca affinis*[N], *Brachystelma alpinum*[N], *Crocosmia pearsei*[N], *Cyrtanthus erubescens*[N], *Disa dracomontana*[N], *Drimia saniensis*[N], *Gladiolus flanaganii*, *G. symonsii*, *Glossostelma xysmalobioides*, *Hesperantha altimontana*[N], *H. curvula*[N], *H. pubinervia*[N], *Moraea vigilans*[N], *Rhodohypoxis incompta*[S], *R. thodiana*[S], *Schizoglossum crassipes*, *S. elingue* subsp. *elingue*, *S. elingue* subsp. *purpureum*, *S. hilliardiae*[N], *Wurmbea burttii*, *W. tenuis* subsp. *australis*. Parasitic Herb: *Harveya leucopharynx*. Low Shrubs: *Erica aestiva* var. *minor*[N], *E. caffrorum* var. *luxurians*[N], *E. flanaganii*, *Eumorphia prostrata*[S], *Euryops brevipes*, *E. evansii* subsp. *parvus*, *Gnidia renniana*, *Helichrysum confertum*[N], *H. drakensbergense*, *H. haygarthii*, *Inulanthera montana*, *Lessertia stipulata*[N], *Lotononis virgata*, *Macowania deflexa*[N], *M. hamata*, *M. sororis*, *Otholobium fumeum*, *Protea nubigena*[N], *Struthiola angustiloba*[N]. Succulent Shrubs: *Delosperma lavisiae*[N], *Othonna burttii*[N].

Conservation Least threatened. The target of 27% has been superseded, since 75% of the unit's surface enjoys statutory protection in the uKhahlamba Drakensberg Park (South Africa). Some patches are also protected in the Sehlabathebe National Park (Lesotho). Erosion very low (76%) and low (19%).

Remarks This unit forms the core of the Drakensberg Alpine CE (as defined by Van Wyk & Smith 2001).

References Acocks (1953, 1988), Killick (1963, 1978a, b, 1994), Edwards (1967), Jacot Guillarmod (1971), White (1978), Hilliard & Burtt (1987), Killick (1990), Hill (1996), Camp (1999b), Van Wyk & Smith (2001).

Gd 8 Lesotho Highland Basalt Grassland

VT 58 *Themeda–Festuca* Alpine Veld (84%) (Acocks 1953). LR 45 Afro Mountain Grassland (55%) (Low & Rebelo 1996).

Distribution Lesotho, Eastern Cape, Free State (and partly also into southern KwaZulu-Natal): Most of the high dissected basalt plateau of Lesotho, including most of the districts of Mokhotlong, Thaba-Tseka, Qacha's Nek and Quthing and the eastern parts of Butha-Buthe, Leribe, Berea, Maseru, Mafeteng and Mohale's Hoek. Extends on the basalt from around 'Makholo (Ben Macdhui) into the Eastern Cape southwards to the vicinity of Barclay East, and westwards along the Witteberge to the vicinity of Lady Grey. Extends in a small area of the northeastern Free State on the high basalt mountains such as Ribbokkop (within the Golden Gate Highlands National Park) and on the top of Oorsprongsberg. Altitude about 1 900–2 900 m. The unit extends to KwaZulu-Natal at the lower parts of the Escarpment edge (e.g. around the Loteni and Mkhomazi Passes). The areas of Drakensberg Afroalpine Heathland (above 2 900 m) are embedded in this unit as are some Lesotho Mires (at higher altitudes). For practical reasons, the vegetation unit includes a small area of high-altitude sandstone (up to about 2 600 m) that is limited to the eastern edge of Lesotho (notably in the Sehlabathebe National Park).

Vegetation & Landscape Features Landscape consists of many plateaus and high ridges of mountains separated by often deep valleys. Although many valley slopes are steep, major cliff faces are only occasionally encountered, especially along parts of the main Maloti Mountain chain. Vegetation is closed, short grassland with many areas also with *Passerina montana*-dominated shrubland. The much smaller shrubs, such as *Chrysocoma ciliata* and *Pentzia cooperi*, are often very common also in clearly disturbed areas (especially on the warmer slopes at higher altitudes). *Chrysocoma ciliata* is the typical component of 'sehalahala scrub' (Anonymous 2000). Within the considerable altitude range in the unit there are many plant species that extend to various altitudinal levels or belts. Also in terms of dominants, for example, *Themeda triandra* tends to be more important at the lower and middle elevations and *Festuca caprina* at higher

altitudes, although there is considerable altitudinal overlap between these species. Although *Kniphofia caulescens* has a wide altitudinal distribution, its large aggregate patches (often hundreds of square metres in extent) are mostly evident in the upper half of the altitudinal range corresponding to larger sponge areas (2 500 to 2 900 m with most mass flowering displays best observed around 2 700 m within Lesotho). The medium-tall distinctive grass *Merxmuellera macowanii* occurs along water courses and drainage lines.

D.J. McDonald

Figure 8.19 Gd 8 Lesotho Highland Basalt Grassland: Mass display of *Kniphofia caulescens* at an altitude of about 2 700 m on basalt at Tiffindell (Eastern Cape) in the southern Drakensberg.

Geology & Soils The area is almost entirely underlain by basaltic lava flows of the Drakensberg Group, with some of the shallow soils covering sandstones of the Clarens Formation (Stormberg Group, Karoo Supergroup) in the form of disintegrating carpets. Soils derived from the basalt have fairly even proportions of coarse sand, fine sand, silt, clay and organic matter. The organic matter increases from about 20% on the slopes to about 26% in the valleys (Herbst & Roberts 1974a). The high organic content (acid, slowly decomposing humus formed largely by decaying grass roots) results in a high water-retention capacity of the soil. Water redistribution through seeps is frequent. Main land type, at least in the South African section, is Ea.

Climate Summer rainfall, with little rain in winter, particularly away from the Northern Escarpment. Much of the area is in a rainshadow with weather stations such as Mokhotlong at an elevation of 2 377 m with a MAP of only 575 mm (Tyson et al. 1976, Killick 1978a). MAP is higher along the eastern edge, for example, 928 mm at Qacha's Nek and also in the southeast, with 686 mm at Barkly East Golf Club. Mean monthly maximum and minimum temperatures for Barkly East Golf Club are 31.4°C and –10.5°C for December and July, respectively. Frost occurs throughout winter and on occasion even in summer at higher elevations. Snow occurs in winter, especially at higher elevations where some light snow can occur in summer. There is a high incidence of lightning in summer and hail is common. See also climate diagram for Gd 8 Lesotho Highland Basalt Grassland (Figure 8.11).

Important Taxa Graminoids: *Bulbostylis humilis* (d), *Cymbopogon dieterlenii* (d), *Elionurus muticus* (d), *Eragrostis curvula* (d), *Festuca caprina* (d), *Harpochloa falx* (d), *Koeleria capensis* (d), *Merxmuellera disticha* (d), *Pentaschistis oreodoxa* (d), *Poa binata* (d), *Scirpus falsus* (d), *Aristida junciformis* subsp. *galpinii*, *Carex glomerabilis*, *Cymbopogon marginatus*, *Eragrostis caesia*, *Helictotrichon turgidulum*, *Luzula africana*, *Merxmuellera drakensbergensis*, *Rendlia altera*. Herbs: *Helichrysum subglomeratum* (d), *Anthospermum herbaceum*, *Cerastium arabidis*, *Cotula hispida*, *Dimorphotheca jucunda*, *Haplocarpha scaposa*, *Helichrysum acutatum*, *H. cerastioides*, *H. setigerum*, *Senecio asperulus*, *Silene burchellii*, *Trifolium burchellianum* subsp. *burchellianum*, *Ursinia montana*, *Zaluzianskya microsiphon*. Geophytic Herbs: *Disa sankeyi*, *D. tysonii*, *Geum capense*, *Moraea modesta*, *Oxalis depressa*, *Rhodohypoxis baurii* var. *baurii*, *R. baurii* var. *confecta*, *R. baurii* var. *platypetala*, *Satyrium longicauda*. Succulent Herb: *Crassula peploides*. Semiparasitic Herb: *Thesium nigrum*. Low Shrubs: *Euphorbia striata*, *Hebenstretia dura*, *Helichrysum infaustum*, *H. odoratissimum*, *H. sessile*, *H. sutherlandii*, *Pentzia cooperi*. Succulent Shrub: *Delosperma crassuloides*.

Biogeographically Important Taxa ([D]Drakensberg endemic, [Dg]Drakensberg endemic extending to Griqualand East) Graminoids: *Ehrharta longigluma*[D], *Helictotrichon galpinii*[D], *Pentaschistis airoides* subsp. *jugorum*[D], *P. exserta*[D], *P. galpinii*[D], *Polevansia rigida*[D], *Restio galpinii*[Dg]. Herbs: *Alchemilla colura*[Dg], *Alepidea pilifera*[D], *Berkheya cirsiifolia*[D], *B. multijuga*[D], *Cephalaria galpiniana* subsp. *simplicior*[D], *Diascia anastrepta*[D], *Felicia linearis*[Dg], *Glumicalyx flanaganii*[D], *G. lesuticus*[D] (Lesotho endemic), *G. montanus*[D], *Helichrysum album*[D], *H. aureum* var. *scopulosum*[Dg], *H. aureum* var. *serotinum*[D], *H. basalticum*[D], *H. bellum*[D], *H. elegantissimum*[D], *H. palustre*[D], *H. subfalcatum*[D], *Heliophila alpina*[D], *Lobelia galpinii*[D], *Psammotropha mucronata* var. *marginata*[D], *Sebaea thodeana*[D], *Senecio tugelensis*[D], *Wahlenbergia polytrichifolia* subsp. *dracomontana*[D], *Zaluzianskya rubrostellata*[D]. Geophytic Herbs: *Corycium alticola*[D], *Cyrtanthus flanaganii*[D], *Disa cephalotes* subsp. *frigida*[D], *D. stricta*[Dg], *D. thodei*[D], *Eucomis schijffii*[D], *Euryops decumbens*[D], *E. evansii* subsp. *evansii*[D], *E. tysonii*[D], *Galtonia regalis*[D], *Gladiolus microcarpus*[D], *Hesperantha schelpeana*[D], *Huttonaea grandiflora*[D], *Moraea alticola*[D], *Rhodohypoxis rubella*[D], *Schizochilus angustifolius*[D], *S. bulbinella*[Dg], *Tulbaghia montana*[D]. Semiparasitic Herb: *Thesium decipiens*[D]. Herbaceous Climber: *Cyphia tysonii*[D]. Low Shrubs: *Helichrysum sessilioides*[D] (d), *Berkheya rosulata*[D], *Clutia nana*[D], *Erica algida*[Dg], *E. dissimulans*[D], *E. dominans*[D], *E. dracomontana*[D], *E. flanaganii*[D], *E. schlechteri*[D], *E. straussiana*[D], *Eumorphia sericea* subsp. *sericea*[D], *Felicia drakensbergensis*[D], *Gnidia compacta*[D], *G. propinqua*[D], *Helichrysum marginatum*[D], *H. trilineatum*[D], *H. witbergense*[D], *Inulanthera thodei*[D], *Passerina drakensbergensis*[D], *Relhania acerosa*[Dg], *R. dieterlenii*[D]. Succulent Shrub: *Delosperma nubigenum*[D].

Endemic Taxa Herbs: *Argyrolobium summomontanum*, *Conium fontanum* var. *alticola*, *Cynoglossum alticola*, *Glumicalyx apiculatus*, *Helichrysum nimbicola*, *Jamesbrittenia beverlyana*, *Lessertia dykei*, *Polygala erubescens*, *Selago melliodora*, *Strobilopsis wrightii*, *Zaluzianskya oreophila*. Geophytic Herbs: *Dryopteris dracomontana*, *Gladiolus saundersii*, *Hesperantha exiliflora*, *Kniphofia hirsuta*, *Moraea alpina*, *Ornithogalum sephtonii*.

Parasitic Herb: *Harveya pulchra*. Low Shrubs: *Clutia alpina*, *Erica caffrorum* var. *aristula*, *E. dracomontana*, *Euryops evansii* subsp. *dendroides*, *E. inops*, *Jamesbrittenia lesutica*, *Macowania pulvinaris*. Succulent Shrubs: *Aloe polyphylla* (Lesotho endemic), *Delosperma aliwalense*, *D. clavipes*.

Conservation Least threatened. Target 27%. Only slightly more than 1% statutorily conserved in the Malekgonyane (Ongeluksnek) Wildlife Reserve, Golden Gate Highlands National Park (both South Africa) and Sehlabathebe National Park (Lesotho). This does not include the portion conserved in the lower reaches of the Bokong Nature Reserve. The planned Maloti-Drakensberg Transfrontier Park would increase the conservation status of the higher-altitude parts of this unit in the north. Almost 10% of the unit has already been transformed, mainly by cultivation, which seldom occurs above an altitude of 2 500 m (usually as narrow isolated belts of maize). This vegetation type has also been affected by the relatively recent completion of the Katse Dam on Malibamatso River and the Mohale Dam on Sengunyane River, representing the highest concrete arch dam and highest rock fill dam on the African continent, respectively. The unit is heavily utilised for grazing (under a communal system; see Tshabalala 1995) by sheep, goats, cattle and donkeys (Chakela 1999), with the most impact at lower altitudes. High-altitude grazing is limited to the warmer months of the year. The large shrub component (*Passerina montana*, *Chrysocoma ciliata* etc.) is probably a consequence of high grazing pressure over many years. Even if grazing has increased the incidence of *P. montana*, it is in turn partly controlled by serving as a major source of fuel for local people. Erosion is very evident in many areas and includes dramatic streaks on some steeper slopes. *Aloe polyphylla* has a relatively high market value for collectors and has vanished from virtually all sites in the Front Range of the Maloti (Anonymous 2000).

L.W. Powrie

Figure 8.20 Gd 8 Lesotho Highland Basalt Grassland on the slopes of the Malibamatso River valley immediately below Katse Dam in northern Lesotho.

Remark 1 Along the southern edge of this unit in the Eastern Cape, some of Bester's (1998) vegetation types occur across the basalt and the lower elevation sedimentary rocks. Only his *Euryops tysonii–Cotula socialis* scrub community is confined to the basalt. Within the Golden Gate Highlands National Park, at least five vegetation types have been identified as occurring exclusively on the basalt (Kay et al. 1993), although there are a number of others that straddle the basalt and sandstone. Further research will reveal whether the flora of the relatively well-collected (in the Sehlabathebe National Park) high-altitude sandstone area is, as Hilliard & Burtt (1987) assert, significantly different from that of the undercollected and often inaccessible basalt areas at the same elevation towards the interior. Hilliard & Burtt (1987) also stated that this elevated sandstone block marks the northeasterly limit of many species from the south (i.e. these species do not continue northwards on the high-altitude basalt substrate). Morris et al. (1993) suggest partitioning this unit into an upper subalpine belt (approximately at 2 900–2 290 m) and a montane belt below 2 290 m. Herbst & Roberts (1974a, b), who included about 30% of the altitude range of their study area in the Drakensberg 'Afro-Alpine Heathland' and the rest in the Lesotho Highland Basalt Grassland, pointed to a very different species composition between these areas and equivalent elevation areas in uKhahlamba Basalt Grassland.

Remark 2 This unit constitutes the major part (in terms of area) of the Drakensberg Alpine Centre of Endemism (Van Wyk & Smith 2001). The Sehlabathebe area has a remarkably high bulbous component such as orchids, which require high soil moisture over prolonged periods of time. The dominant shrub of the slopes of the Western Lesotho Basalt Shrubland (*Leucosidea sericea*) seems, curiously, to be largely absent from even the lower slopes of this unit.

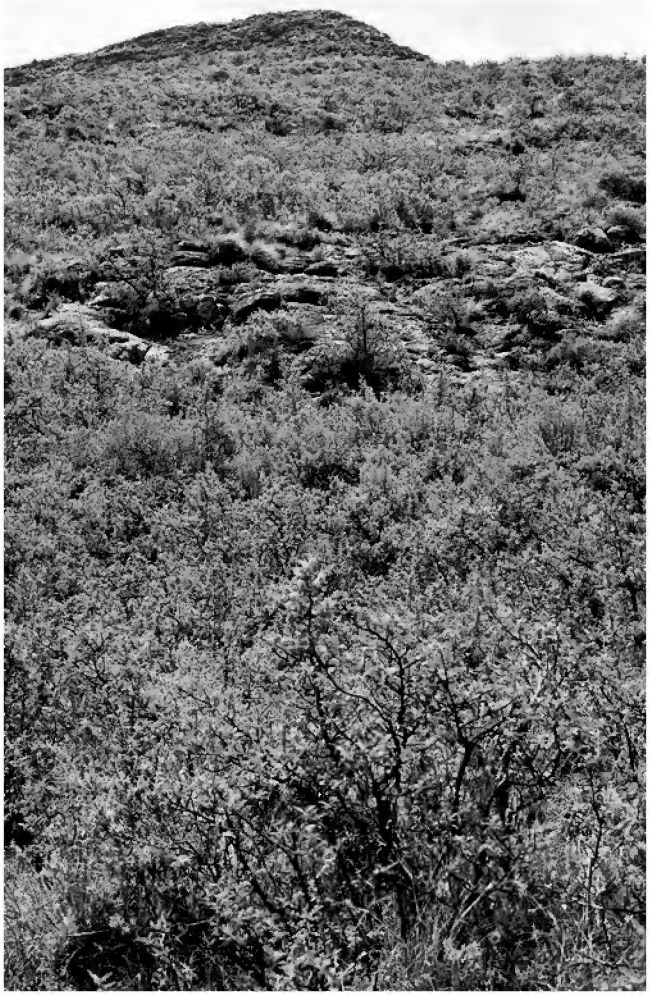
References Herbst & Roberts (1974a, b), Killick (1978a, b), Potgieter (1982), Wieland (1982), Martin (1986), Hilliard & Burtt (1987), Backéus (1988), Morris (1990), Mokuku (1991), Kay et al. (1993), Morris et al. (1993), Morris (1994), Bester (1998), Willis et al. (1999), Anonymous (2000), Wyk & Smith (2001), Kobisi (2005).

Gd 9 Western Lesotho Basalt Shrubland

VT 58 *Themeda–Festuca* Alpine Veld (49%), VT 48 *Cymbopogon–Themeda* Veld (sandy) (43%) (Acocks 1953). LR 45 Afro Mountain Grassland (87%) (Low & Rebelo 1996).

Distribution Lesotho: Almost all confined to the Maseru and Mafeteng Districts. Relatively limited area on lower-altitude basalt along the southwestern end of the Front Range from around Bushman's Pass in the north to around Matelile/Malealea in the south and including the lower basalt slopes of the broad Makhaleng River Valley, including the Ramabanta area. Altitude 1 680–2 400 m, mostly 1 780–1 820 m.

Vegetation & Landscape Features Gentle to sometimes steep lower mountain slopes of basalt supporting medium-tall extensive shrublands alternating in places with patches of grassland. Overwhelmingly dominated by a shrubby form of *Leucosidea sericea*, whose dominance is not limited to drainage lines.



L.W. Powrie

Figure 8.21 Gd 9 Western Lesotho Basalt Shrubland: Dense shrubland dominated by *Leucosidea sericea*, with some *Rhus pyroides* at an altitude of 2 025 m northwest of Ha Ramabanta, Lesotho.

Geology & Soils The Jurassic basalts of the Drakensberg Group (Karoo Supergroup) dominate this area. Soils are shallow to sometimes deep, with a significantly high organic content.

Climate Summer rainfall, with very little rain in winter. MAT is the highest of the four main grassland types on basalt. Snow is of limited duration in winter. See also climate diagram for Gd 9 Western Lesotho Basalt Shrubland (Figure 8.11).

Important Taxa Tall Shrubs: *Leucosidea sericea* (d), *Buddleja loricata*, *Rhamnus prinoides*, *Rhus pyroides*. Low Shrubs: *Chrysocoma ciliata* (d), *Felicia muricata*, *Hebenstretia dura*, *Helichrysum splendidum*, *Jamesbrittenia stricta*, *Rhus divaricata*. Graminoids: *Digitaria eriantha* (d), *Eleocharis dregeana*, *Festuca caprina*, *Hyparrhenia hirta*, *Merxmuellera stereophylla*, *Pennisetum thunbergii*. Herbs: *Ajuga ophrydis*, *Conium chaerophylloides*, *Cysticapnos pruinosa*, *Felicia petiolata*, *Galium capense* subsp. *garipense*, *Geranium magniflorum*, *G. robustum*, *Helichrysum aureum* var. *monocephalum*, *Ipomoea oblongata*, *Manulea crassifolia* subsp. *crassifolia*, *Myosotis afropalustris*, *Pimpinella caffra*, *Polygala gracilenta*, *P. rhinostigma*, *Rumex lanceolatus*, *Salvia repens* var. *repens*, *Sebaea repens*, *Senecio glaberrimus*, *Stachys dregeana*. Geophytic Herbs: *Bulbine frutescens*, *Corycium dracomontanum*, *Dierama robustum*, *Dipcadi viride*, *Gladiolus permeabilis* subsp. *edulis*, *Kniphofia ritualis*.

Biogeographically Important Taxa (both Drakensberg endemics) Herbs: *Alepidea pilifera*, *Diascia integerrima*.

Conservation Least threatened. Target 28%. None conserved in statutory conservation areas. About 16% already transformed, mainly by cultivation. Being close to major concentrations of human settlements in the lowlands, it has probably been subjected to prolonged grazing pressure. Although erosion is high in places, it appears far less eroded than the surrounding lowlands. Although a number of alien plants are concentrated around settlements, they do not appear to have had a major impact on the vegetation yet. *Aloe polyphylla* has a relatively high market value for collectors and has vanished from virtually all sites in the Front Range of the Maloti (Anonymous 2000).

Remarks This unit approximates the southern part of what has been regarded as the Foothills Ecological Zone (Anonymous 2000), although this zone often includes the sandstone belt below the basalt. Very little is known about this unit and future research should attempt to determine to what extent it may be a derived type. Of interest is that some of the typical species (*Leucosidea sericea*, *Rhamnus pyroides*, *Buddleja saligna*) are indicative of forest precursors (C.J. Geldenhuys, personal communication). *L. sericea* tends to invade formerly disturbed (overgrazed) wet grasslands. It is not only the case in Lesotho, but also in the bordering regions where, for instance, Eastern Free State Wet Grassland and Drakensberg Montane meet (Qwaqwa and Golden Gate Highlands National Parks, Van Rheenen's Pass near Harrismith).

References Anonymous (2000), Kobisi (2005).

Gd 10 Drakensberg Afroalpine Heathland

VT 58 *Themeda–Festuca Alpine* Veld (99%) (Acocks 1953). LR 46 Alti Mountain Grassland (81%) (Low & Rebelo 1996).

Distribution Lesotho and very marginally also in KwaZulu-Natal Province: The highest plateaus and mountain ridges above an altitude of about 2 900 m in northeastern Lesotho. This includes the highest mountain in southern Africa (Thabana-Ntlenyana, 3 482 m). Further away from the edge of the Drakensberg Escarpment it is particularly extensive in the area of the Tlaeen Pass and Pass of Guns (between Mokhotlong and Oxbow) with good examples visible on the Kotisephola Pass (between Sani Pass top and Mokhotlong), Mafika-Lisiu Pass (between Lejone and Pitseng) and Matebeng Pass (between Sehlabathebe and Sehonghong). Altitude range 2 900–3 400 m, mainly 2 980–3 110 m.

Vegetation & Landscape Features Rolling plateaus with steep slopes in places. Very variable but short vegetation from shrub-dominated areas, for example by *Helichrysum trilineatum*, to grassland with shrubs, to grassland with few shrubs. The most dominant grass is *Merxmuellera disticha* (Herbst 1971, Herbst & Roberts 1974b, Morris et al. 1993). Cushion plants (e.g. *H. sessilioides*) and plants forming low mats (e.g. *H. praecurrens*) are common. As elsewhere in the highlands of Lesotho, *Chrysocoma ciliata* is common in disturbed areas and even in some apparently little disturbed areas. Many Lesotho Mires are embedded in this unit. The medium-tall grass *M. drakensbergensis* extends well away from watercourses and drainage lines.

Geology & Soils The area occurs entirely on basalt of the Drakensberg Group (Karoo Supergroup). Soils are Mollisols indicating an Udic moisture regime and frigid temperature regime. Frost action is important in alpine soil formation (Mokuku 1991). The freezing and thawing of the soil heaves the soil material, resulting in gradual removal of finer soil particles downslope, mainly from the existing micro-erosion terraces. Soils derived

C.R. Scott-Shaw

Figure 8.22 Gd 10 Drakensberg Afroalpine Heathland: Moist heathland dominated by *Erica dominans* and *E. glaphyra* on the summit of the Eastern Buttress, Amphitheatre area, with the steep cliffs of the uKhahlamba Basalt Grassland (Gd 7) in the background.

from the basalt have fairly even proportions of coarse sand, fine sand, silt, clay and, importantly, organic matter (around 20%). In many areas the soil is shallow, with surface rock, including some areas with mostly rock rubble, for example on Thabana-Ntlenyana (Killick 1990).

Climate Summer rainfall, but subject to some precipitation from cold fronts in winter. MAP has a considerable range, with 1 609 mm at the top of the Organ Pipes Pass on the Escarpment at 2 927 m elevation, and only 634 mm at a point 365 m higher at 3 292 m, but between 15 and 20 km away from the Escarpment edge (Killick 1979). There is thus a rapid decline in MAP from near (2–3 km) the edge of the Escarpment (but further in the Oxbow area) to the interior even at higher elevations (Bawden & Carrol 1968, Chakela 1999). The mean annual temperature of about 4.0°C is lower than that of any of the other vegetation units. Frost occurs probably more than half the year, including occasionally in summer. Letseng-la-Terae, at an altitude of 3 000 m, holds the record for the lowest temperature ever recorded in Lesotho (–20.4°C in June 1967). See also climate diagram for Gd 10 Drakensberg Afroalpine Heathland (Figure 8.11).

Important Taxa Low Shrubs: *Chrysocoma ciliata* (d), *Anisodontea julii* subsp. *pannosa*, *Erica glaphyra*, *Pentzia cooperi*, *Selago flanaganii*, *Syncolostemon macranthus*. Graminoids: *Merxmuellera drakensbergensis* (d), *Pentaschistis aurea* subsp. *pilosogluma*.

Biogeographically Important Taxa ([D]Drakensberg endemic, [Dg]Drakensberg endemic extending to Griqualand East) Low Shrubs: *Erica dominans*[D] (d), *Eumorphia sericea* subsp. *sericea*[D] (d), *Helichrysum trilineatum*[D] (d), *Clutia nana*[D], *Erica frigida*[D], *E. thodei*[Dg], *Euryops decumbens*[D], *E. montanus*[D], *Felicia drakensbergensis*[D], *Gnidia propinqua*[D], *Helichrysum milfordiae*[D], *H. witbergense*[D], *Inulanthera thodei*[D]. Succulent Shrub: *Delosperma nubigenum*[D]. Herbs: *Cotula lineariloba*[D], *Felicia uliginosa*[D], *Glumicalyx lesuticus*[D] (Lesotho endemic), *Helichrysum basalticum*[D], *H. bellum*[D], *H. palustre*[D], *Heliophila alpina*[D], *Lobelia galpinii*[D], *Sebaea thodeana*[D]. Geophytic Herbs: *Romulea luteoflora* var. *sanisensis* (specific link to Hantam-Roggeveld CE), *Saniella verna*[D] (generic link to Hantam-Roggeveld CE). Graminoid: *Ehrharta longigluma*[D].

Endemic Taxa Low Shrubs: *Euryops acraeus*, *Helichrysum pagophilum*, *Muraltia flanaganii*. Herbs: *Aster erucifolius*, *Cotula radicalis*, *Helichrysum lineatum*, *H. praecurrens*, *Jamesbrittenia jurassica*, *Manulea platystigma*, *Psammotropha obtusa*, *Zaluzianskya chrysops*, *Z. turritella*. Geophytic Herbs: *Disa basutorum*, *Hesperantha alborosea*, *H. altimontana*, *Wurmbea pusilla*.

Conservation Least threatened. Target 27%. About 2% statutorily conserved in the uKhahlamba Drakensberg Park as well as in the upper parts of the Bokong Nature Reserve. The planned Maloti-Drakensberg Transfrontier Park could conserve almost all the area of this unit. Very little has been transformed, but grazing pressure in summer is high. Already in 1938, Staples & Hudson referred to a considerable increase in *Helichrysum trilineatum*, *Passerina montana* and an *Erica* species and a *Pentzia* species 'in places above 9500 feet' (2 896 m). Although the increase in *H. trilineatum* may be promoted by its poor palatability to stock, it may be partly counteracted by its use 'as fuel, the branches burning readily when green' (Hilliard 1983).

Remarks The *Erica–Helichrysum–Eumorphia* sedge heath of Jacot Guillarmod (1971), although occasionally found on cold wet slopes below the 2 900 m, is 'the climax community over most of the area only above 2 900 metres'. Morris et al. (1993) supported the notion of general altitudinal limit of 2 900 m for this unit, but also suggested that it extends to somewhat lower altitudes on southern slopes. This unit also comprises the *Merxmuellera drakensbergensis–Festuca caprina* high-altitude Austro-afro Alpine grassland of Du Preez & Bredenkamp (1991). The often common *Themeda triandra* in the eastern grasslands of southern Africa is rare in this unit. Families rich in geophytes (Iridaceae, Hyacinthaceae, Orchidaceae) appear to lose significance with increasing altitude (Herbst & Roberts 1974b), yet orchids are prominent along the Escarpment edge (Killick 1990). The strong diminishing precipitation gradient from the Escarpment edge inland probably helps explain the apparent contradictions between especially earlier accounts of the flora and vegetation based on studies on the edge of the Escarpment and what is observed further into Lesotho. It could be argued that the narrow strip on top of the Escarpment would be better grouped (as a subtype) with the uKhahlamba Basalt Grassland.

References Killick (1963, 1978a, b, 1990), Edwards (1967), Jacot Guillarmod (1971), Herbst & Roberts (1974b), White (1978), Hilliard & Burtt (1987), Du Preez & Bredenkamp (1991), Morris et al. (1993), Hill (1996), Van Wyk & Smith (2001), Kobisi (2005).

Dry Highveld Grassland

Highveld grasslands are found on the extensive central plateau of South Africa. The topography is flat to undulating, occasionally broken by small mountains, typically found in the Free State, or incised river valleys, such as the Orange, Vaal and Olifants Rivers. The major environmental factor controlling vegetation patterns and the recognition of different vegetation types is

annual rainfall, which forms an east to west gradient of decreasing moisture across the Highveld.

Dry Highveld Grassland prevails in the western regions of the Grassland Biome where annual rainfall is below 600 mm per annum (Figure 8.23). These grasslands therefore fall into the 'sweet' grassland type with a predominance of chloridoid grasses. These areas are found mostly within the Free State, North-West and Eastern Cape Provinces in a north-south band. The grassland types are mostly plains grasslands distinguished primarily on substrate characteristics, but also include the topographically complex, steep mountain grasslands of the Karoo Escarpment. Also included within Dry Highveld Grassland are a number of intrazonal units containing shrubland on koppies or woodland on other substrates (Figure 8.24). These shrublands form a distinctive structural vegetation type within the matrix of grasslands and are restricted to rocky slopes and outcrops where the surface rockiness is high and where soils are mostly shallow and stony.

Gh 1 Karoo Escarpment Grassland

VT 60 Karroid *Danthonia* Mountain Veld (69%) (Acocks 1953). LR 44 South-eastern Mountain Grassland (69%) (Low & Rebelo 1996).

Distribution Eastern, Northern and Western Cape Province: Occurs on the Karoo Escarpment, running in an east-west direction from Molteno to Noupoort in the north, and from Somerset East in a northwesterly direction towards Nieu-Bethesda. Also found on the north-facing slopes of the Winterberg Mountains around Tarkastad. The westernmost locality is on the highest-altitude flat-topped mesas of the Escarpment in the Karoo National Park near Beaufort West. Altitude about 1 100–2 502 m at the summit of the Kompasberg.

Vegetation & Landscape Features Mountain summits, low mountains and hills with wiry, tussock grasslands, usually dominated by *Merxmuellera disticha*. Other common species include the grasses typical of dry grasslands (genera *Eragrostis*,

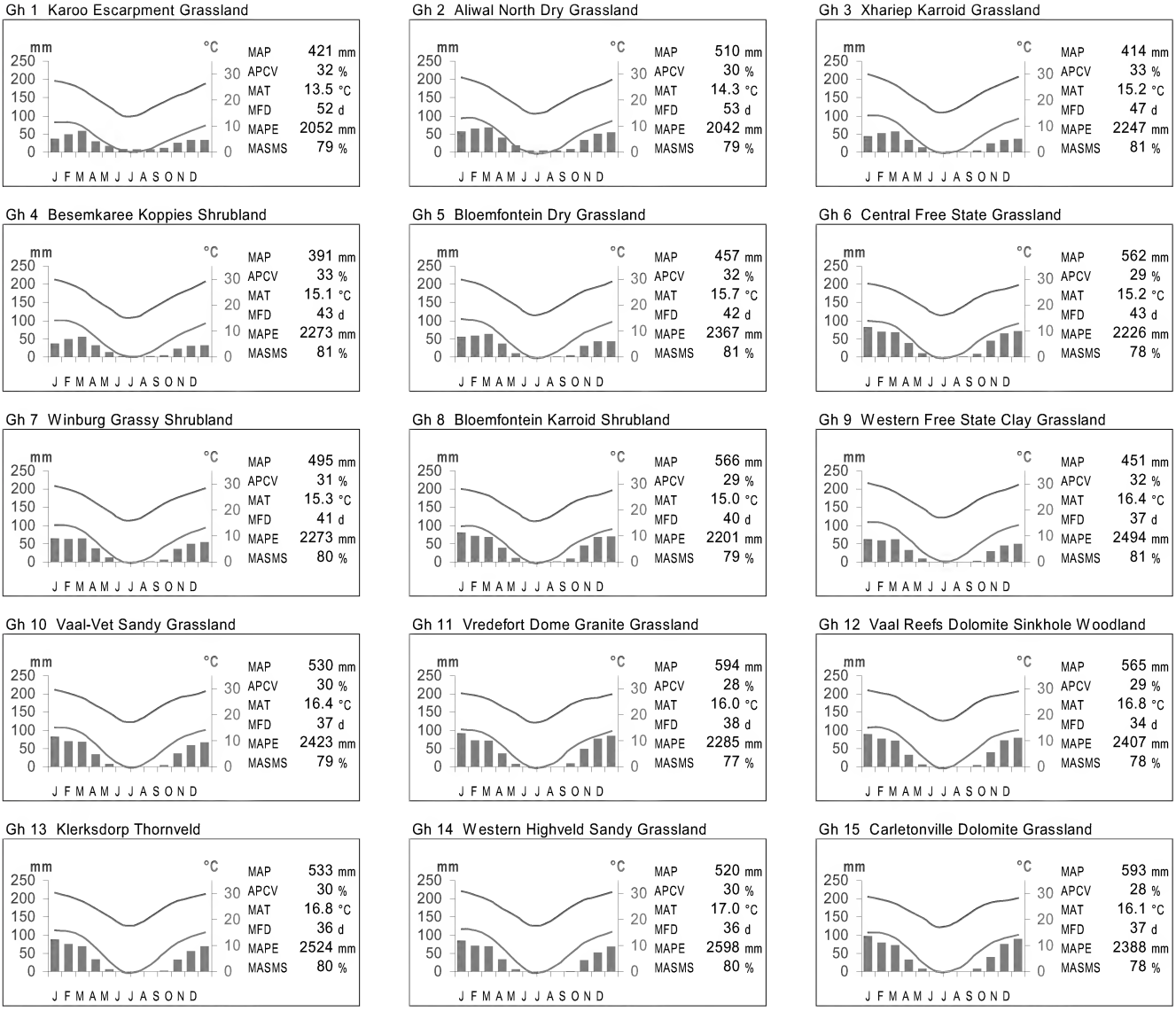


Figure 8.23 Climate diagrams of the Dry Highveld Grassland Bioregion units. Blue bars show the median monthly precipitation. The upper and lower red lines show the mean daily maximum and minimum temperature respectively. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days (days when screen temperature was below 0°C); MAPE: Mean Annual Potential Evaporation; MASMS: Mean Annual Soil Moisture Stress (% of days when evaporative demand was more than double the soil moisture supply).

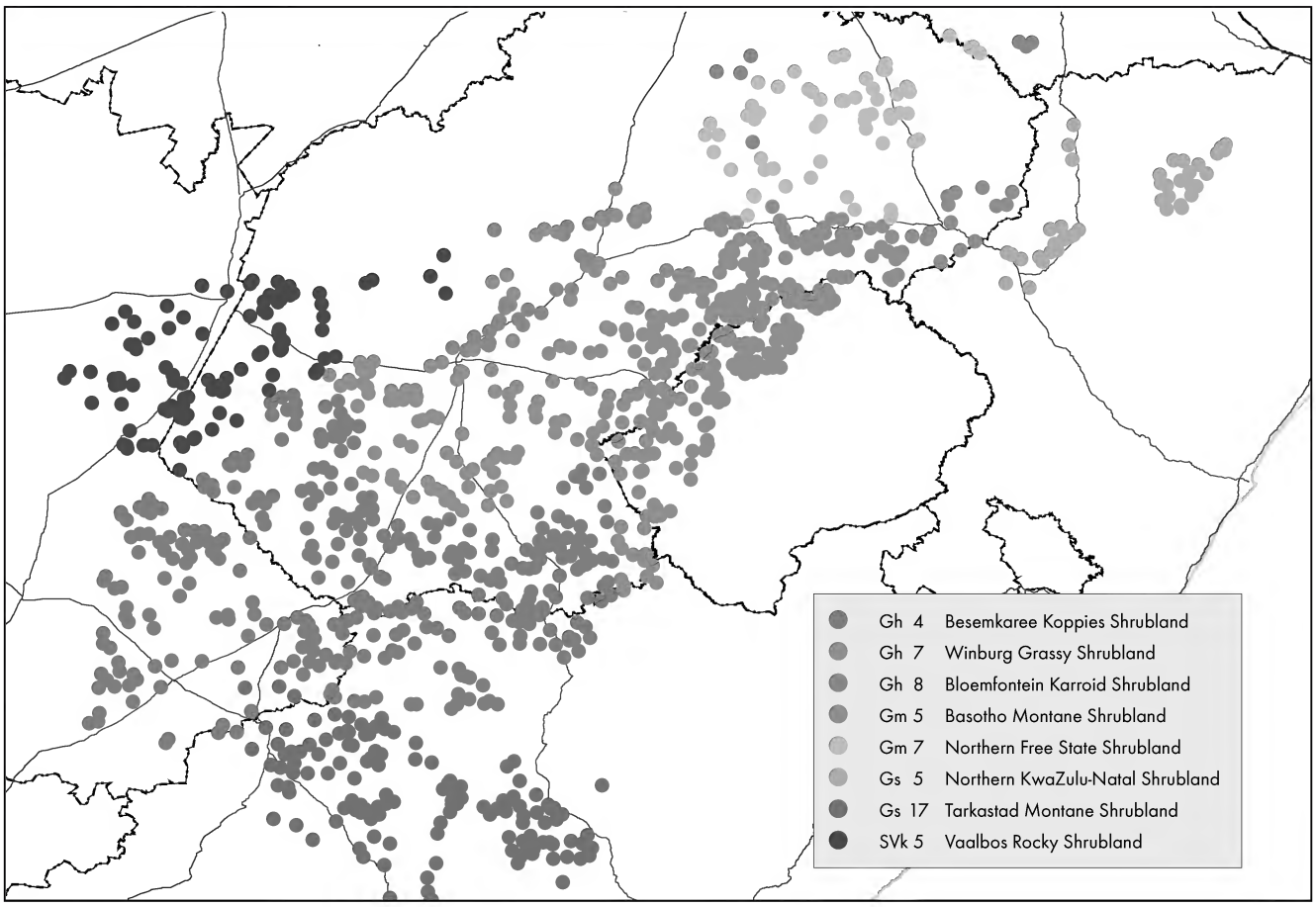


Figure 8.24 Simplified map of patches of various shrubland units (see the legend) occupying special geological and topographical situations within the Grassland Biome.

Tetrachne, *Karroochloa*, *Helictotrichon*, *Melica*, *Tragus*, *Elionurus* and *Aristida*). An important low shrub component occurs throughout this grassland unit.

Geology & Soils Shallow soils typical of Ib, Fb and Fc land types on mudstones and sandstones of the Beaufort Group (Karoo Supergroup). Jurassic dolerite intrusions form ridges in the area.

Climate Rainfall showing minor (possibly insignificant) peaks in March and November–December. Very dry winters. MAP 300–580 mm, increasing from west to east as well as with increasing elevation. The coefficient of variation of MAP 27–36% across the unit. The incidence of frost is from less than 20 to more than 100 days, the higher values occurring at higher elevation. There may be a number of days of snow per year, especially at higher elevations and near the edge of the Great Escarpment. See also climate diagram for Gh 1 Karoo Escarpment Grassland (Figure 8.23).

Important Taxa Graminoids: *Aristida congesta* (d), *A. diffusa* (d), *Cynodon incompletus* (d), *Ehrharta calycina* (d), *Eragrostis chloromelas* (d), *Heteropogon contortus* (d), *Merxmuellera disticha* (d), *Themeda triandra* (d), *Tragus koelerioides* (d), *Cymbopogon pospischilii*, *Cynodon dactylon*, *Elionurus muticus*, *Eragrostis curvula*, *E. lehmanniana*, *E. obtusa*, *Eustachys paspaloides*, *Karroochloa purpurea*, *Melica decumbens*, *Panicum stapfianum*, *Tetrachne dregei*. Herbs: *Berkheya pinnatifida*, *Convolvulus sagittatus*, *Dianthus caespitosus* subsp. *caespitosus*, *Diascia capsularis*, *Dimorphotheca zeyheri*, *Galium capense* subsp. *capense*, *Gazania krebsiana* subsp. *krebsiana*, *Hebenstretia dentata*, *Helichrysum nudifolium* var. *nudifolium*, *H. tysonii*, *Lasiospermum bipinnatum*, *Lepidium africanum* subsp. *africanum*, *Rumex lanceolatus*, *Senecio asperulus*. Geophytic Herbs: *Boophone disticha*, *Cheilanthes bergiana*, *C. hirta*, *Eucomis autumnalis* subsp. *autumnalis*, *Haemanthus humilis* subsp. *humilis*, *Oxalis depressa*. Succulent Herb: *Tripteris aghillana* var. *integrifolia*. Low Shrubs: *Chrysocoma ciliata* (d), *Felicia muricata* (d), *Anthospermum rigidum* subsp. *pumilum*, *Atriplex semibaccata* var. *appendiculata*, *Elytropappus rhinocerotis*, *Erica caespitosa*, *E. caffrorum* var. *caffrorum*, *E. woodii*, *Eriocephalus eximius*, *Euryops annae*, *E. anthemoides* subsp. *astrotrichus*, *E. candollei*, *E. floribundus*, *E. oligoglossus* subsp. *oligoglossus*, *Felicia filifolia* subsp. *filifolia*, *Helichrysum asperum* var. *albidulum*, *H. dregeanum*, *H. lucilioides*, *H. niveum*, *H. rosum*, *H. zeyheri*, *Indigofera sessilifolia*, *Limeum aethiopicum*, *Nemesia fruticans*, *Passerina montana*, *Selago albida*, *S. saxatilis*, *Senecio burchellii*, *Sutera pinnatifida*, *Wahlenbergia albens*. Succulent Shrubs: *Euphorbia clavarioides* var. *clavarioides*, *E. mauritanica*. Tall Shrubs: *Cliffortia arborea*, *Diospyros austro-africana*, *Rhus lucida*.

Biogeographically Important Taxa ([C]Camdebo endemic, [D]Link to Drakensberg Alpine CE) Graminoids: *Pentaschistis cirrhulosa*[D], *P. microphylla*[D]. Low Shrubs: *Helichrysum sessile*[D], *Pentzia cooperi*[D]. Succulent Shrub: *Delosperma congestum*[D]. Succulent Herb: *Duvalia modesta*[C].

Endemic Taxa Graminoid: *Schoenoxiphium rufum* var. *dregeanum*. Herbs: *Lithospermum diversifolium*, *Wahlenbergia sphaerica*. Geophytic Herbs: *Kniphofia acraea*, *Syringodea pulchella*. Low Shrubs: *Euryops dentatus*, *E. trilobus*, *Helichrysum scitulum*, *Selago bolusii*. Succulent Shrub: *Delosperma gramineum*.

R. Clark

Figure 8.25 Gh 1 Karoo Escarpment Grassland: Dry grassland with *Merxmuellera stricta* in the Sneeuberg (a view towards the summit reaching 2 100 m) in the Graaff-Reinet area (Eastern Cape), with shrubby species such as *Rhus dregeana*, *Melolobium microphyllum* and *M. candicans* scattered on the slopes.

Free State to around Wepener and De Wetsdorp. Altitude 1 320–1 660 m.

Vegetation & Landscape Features Broken terrain and irregular plains supporting open grassland with patches of dwarf karroid shrubs (similar to Gh 3 Xhariep Karroid Grassland). The dominance of grasses *Themeda triandra* and *Tetrachne dregei* is notable. In years of low precipitation the dwarf karroid shrubs become more visible, especially during the winter months and early spring.

Geology & Soils Alternating layers of mudstone and sandstone of the Tarkastad Subgroup (Beaufort Group, Karoo Supergroup) dominate the undulating topography. In areas protected from erosion, a sandy layer also covers the clayey subsoils. About two thirds of the soils of the area is dominated by soils with diagnostic pedocutanic and prismacutanic (dark clayey) B-horizons of the Db land type. In this land type the dominant soil forms are Estcourt, Rensburg and Oakleaf forms. Dominant land type Db, followed by Da.

Conservation Least threatened. Target 24%. Nearly 3% statutorily conserved in the Mountain Zebra and Karoo National Parks as well as in the Tsolwana and Karoo Nature Reserves. Slightly higher portions also protected in game farms and private nature reserves, such as Buchanon, Asanta Sana, Samara, Karoo Safaris, Hoeksfontien, Glen Harry, Oudekraal and Rupert. Erosion moderate (49%) and high (42%).

Remark 1 This unit occurs across a wide geographical area with associated floristic variability. The biome classification of this unit is controversial since both Karoo and Grassland elements are strongly represented in the species composition. However, the presence of many (and dominant) C_3 grasses surrounded by vegetation containing C_4 grasses as well as the remarkable share of fynbos-related elements (*Elytropappus rhinocerotis*, *Erica caffra*, *Cliffortia ramosissima*, *Ursinia montana*, *Pentzia cooperi*, *Euryops* species, *Passerina montana*, *Cliffortia arborea* and also a new species of *Erica*—E.G.H. Oliver, personal communication) supports the decision to classify this vegetation within the Grassland Biome (see also Acocks 1988, Low & Rebelo 1996).

Remark 2 The mountain ranges with this arid type of grassland are one of the centres of diversification of the genus *Euryops* (Nordenstam 1968).

References Acocks (1953, 1988), Van der Walt (1980), Palmer (1991a, b), Low & Rebelo (1996), Rubin & Palmer (1996), Hoare (1997), Hoare & Bredenkamp (2001), Brown & Bezuidenhout (2005).

Gh 2 Aliwal North Dry Grassland

VT 50 Dry *Cymbopogon–Themeda* Veld (47%), VT 49 Transitional *Cymbopogon–Themeda* Veld, (33%) (Acocks 1953). LR 37 Dry Sandy Highveld Grassland (69%) (Low & Rebelo 1996).

Distribution Eastern Cape and Free State Provinces: In the broad surrounds of Aliwal North, running in an east-west direction along the northern foothills of the Stormberg Plateau, extending northwards up the Caledon River Valley in the

Climate Overall MAP 510 mm, reaching 600 mm in Wepener (northeastern region of the unit), falling predominantly during summer. MAT around 14°C, with more than 50 days of frost. See also climate diagram for Gh 2 Aliwal North Dry Grassland (Figure 8.23).

Important Taxa Graminoids: *Aristida adscensionis* (d), *A. congesta* (d), *Cymbopogon pospischilii* (d), *Cynodon incompletus* (d), *Elionurus muticus* (d), *Eragrostis chloromelas* (d), *E. lehmanniana* (d), *E. obtusa* (d), *Heteropogon contortus* (d), *Microchloa caffra* (d), *M. kunthii* (d), *Setaria sphacelata* (d), *Themeda triandra* (d), *Tragus koelerioides* (d), *Aristida diffusa*, *Cynodon dactylon*, *Cyperus usitatus*, *Digitaria eriantha*, *Eragrostis capensis*, *E. curvula*, *E. plana*, *Helictotrichon turgidulum*, *Sporobolus fimbriatus*, *Tetrachne dregei*, *Trichoneura grandiglumis*, *Triraphis andropogonoides*. Herbs: *Berkheya onopordifolia* var. *onopordifolia*, *Galium capense* subsp. *capense*, *Gazania krebsiana* subsp. *krebsiana*, *Helichrysum rugulosum*, *Hermannia coccocarpa*, *Indigofera alternans*, *Jamesbrittenia aurantiaca*, *Lotononis listii*, *Nolletia ciliaris*, *Pseudognaphalium luteo-album*, *Salvia stenophylla*, *Selago densiflora*, *Trichogyne verticillata*. Geophytic Herb: *Oxalis depressa*. Low Shrubs: *Helichrysum dregeanum* (d), *Pentzia globosa* (d), *Anthospermum rigidum* subsp. *pumilum*, *Atriplex semibaccata* var. *appendiculata*, *Berkheya annectens*, *Chrysocoma ciliata*, *Euryops annae, E. oligoglossus* subsp. *oligoglossus, Felicia muricata*, *Helichrysum niveum*, *H. rosum*, *Nenax microphylla*, *Selago saxatilis*, *Senecio burchellii*.

Conservation Least threatened. Target 24%. Only small patch statutorily conserved in the Caledon Nature Reserve. Some 12% already transformed for cultivation and building of dams (Rolandseck, Smithfield, Welbedacht). This grassland is also prone to karoo-bush encroachment when overgrazed. Erosion moderate (43%), low (34%) and high (22%).

Remarks This vegetation unit is interspersed with rock outcrops capped with dolerite upon which Gh 4 Besemkaree Koppies Shrubland is found. It also borders on the Orange River, along which a riverine shrubland/thicket is found and forms the transition between high-altitude grassland vegetation and low-altitude karroid shrublands.

References Acocks (1953, 1988), Werger (1973a, b, 1980), Du Preez & Bredenkamp (1991), Malan (1993, 1998), Hoare (1997), Hoare & Bredenkamp (2001).

Gh 3 Xhariep Karroid Grassland

VT 36 False Upper Karoo (90%) (Acocks 1953). LR 52 Eastern Mixed Nama Karoo (90%) (Low & Rebelo 1996).

Distribution Free State Province and very slightly into the Northern Cape Province: Southern regions including the vicinity of Luckhoff (west), Edenburg (north), Gariep Dam (south) and Smithfield (east). Altitude 1 260–1 560 m.

Vegetation & Landscape Features Extensive, even or slightly undulating bottomland flats forming a matrix of large landscape patches interrupted by high dolerite sills, koppies and conspicuous ring dykes (bearing Gh 4 Besemkaree Koppies Shrubland) and supporting low- to medium-height, open grassland intermingled with small patches of dwarf karroid shrubs. The grass element becomes more visible, especially in summer, particularly in years of high precipitation. The open grassland intermingled with patches of dwarf karroid shrubs resembles the physiognomy of the Gh 2 Aliwal North Dry Grassland, although many of the species show a greater affinity for the slightly lower rainfall than in the latter grassland unit. Low cover of grasses such as *Themeda triandra*, *Cymbopogon pospischilii* and *Digitaria eriantha* is indicative of the relatively low rainfall. In years of low precipitation, dwarf karroid shrubs become more prominent and barren patches of soil become more visible, especially during the winter months and early spring.

Geology & Soils Alternating layers of mudstone and sandstone mostly of the Permian Adelaide Subgroup (Beaufort Group, Karoo Supergroup). Part of the area is covered with soils with diagnostic pedocutanic and prismacutanic (dark clayey) B-horizons and belongs to soil forms such as Estcourt, Rensburg and Oakleaf. In some areas, especially towards the more arid west, patches of calcrete on the soil surface are notable—here the soil forms such as Kimberley and Plooysburg prevail (dwarf karroid shrubs usually concentrate on these areas of limestone-rich patches). The entire area has been classified as Da or Db land types.

Climate Seasonal climatic region, with summer rainfall peaking in early autumn, and with overall relatively low MAP (slightly above 410 mm). Some of the localities can, however, reach mean yearly rainfall values as high as 580 mm (Edenburg). MAT around 15°C, but winter frost very common (around 50 days on average). See also climate diagram for Gh 3 Xhariep Karroid Grassland (Figure 8.23).

Important Taxa Graminoids: *Aristida adscensionis* (d), *A. canescens* (d), *A. congesta* (d), *Chloris virgata* (d), *Cynodon incompletus* (d), *Eragrostis chloromelas* (d), *E. lehmanniana* (d), *E. obtusa* (d), *Fingerhuthia africana* (d), *Panicum coloratum* (d), *P. stapfianum* (d), *Themeda triandra* (d), *Tragus koelerioides* (d), *Aristida diffusa*, *Cymbopogon pospischilii*, *Digitaria eriantha*, *Eragrostis curvula*, *Sporobolus fimbriatus*. Herbs: *Gazania krebsiana* subsp. *krebsiana* (d), *Convolvulus boedeckerianus*, *Dimorphotheca zeyheri*, *Hermannia coccocarpa*, *Indigofera alternans*, *Lepidium africanum* subsp. *africanum*, *Lessertia pauciflora*, *Rumex lanceolatus*, *Salvia stenophylla*, *Selago densiflora*. Geophytic Herbs: *Moraea pallida* (d), *Oxalis depressa*. Succulent Herb: *Tripteris aghillana* var. *integrifolia*. Low Shrubs: *Chrysocoma ciliata* (d), *Eriocephalus ericoides* (d), *E. spinescens* (d), *Felicia filifolia* subsp. *filifolia* (d), *F. muricata* (d), *Pentzia globosa* (d), *P. incana* (d), *Amphiglossa triflora*, *Aptosimum elongatum*, *Atriplex semibaccata* var. *appendiculata*, *Berkheya annectens*, *Gnidia polycephala*, *Helichrysum asperum* var. *albidulum*, *H. dregeanum*, *H. lucilioides*, *Lycium cinereum*, *Melolobium candicans*, *Nenax microphylla*, *Oligomeris dregeana*, *Osteospermum spinescens*, *Rosenia humilis*, *Selago saxatilis*, *Wahlenbergia albens*, *W. nodosa*. Succulent Shrubs: *Euphorbia clavarioides* var. *clavarioides*, *Hertia pallens*, *Ruschia hamata*, *R. rigida*, *Salsola calluna*, *S. glabrescens*. Tall Shrub: *Rhus ciliata*.

Endemic Taxa Herb: *Manulea flanaganii*. Succulent Shrubs: *Phyllobolus rabiei*, *Ruschia calcarea*.

Conservation Least threatened. Target 24%. About 2.5% statutorily conserved in Gariep Dam, Tussen Die Riviere, Kalkfontein Dam, Oviston, Wurasdam and Rolfontein Nature Reserves. Some 4% already transformed by cultivation and dam-building (Bethulie, Gariep, Kalkfontein, Straussfontein and Tierpoort Dams). This dry grassland is prone to encroachment of low, unpalatable karroid shrubs when exposed to heavy grazing. Erosion moderate (71%) and low (19%).

L. Mucina

Figure 8.26 Gh 3 Xhariep Karroid Grassland: Herb-rich dry grassland with prominent species of *Helichrysum* near Donkerpoort (southwest of Springfontein, southern Free State).

Remarks Xhariep Karroid Grassland occupies a central position along a rainfall gradient between Gh 5 Bloemfontein Dry Grassland (to the north) and dwarf karroid shrub-dominated NKu 4 Eastern Upper Karoo (to the south). Most of the unit was viewed by Acocks (1953) as a karoo type of vegetation that had originally been grassland.

References Acocks (1953, 1988), Werger (1973a, b, 1980), Du Preez & Bredenkamp (1991), Malan (1993, 1998), Malan et al. (1994).

Gh 4 Besemkaree Koppies Shrubland

VT 36 False Upper Karoo (79%) (Acocks 1953). LR 52 Eastern Mixed Nama Karoo (76%) (Low & Rebelo 1996).

Distribution Northern Cape, Free State and Eastern Cape Provinces: On plains of Eastern Upper Karoo (between Richmond

L. Mucina

Figure 8.27 Gh 4 Besemkaree Koppies Shrubland: Open shrublands of *Rhus erosa* on a dolerite koppie near Smithfield (Free State).

and Middelburg in the south and the Orange River) and within dry grasslands of the southern and central Free State. Extensive dolerite-dominated landscapes along the upper Orange River belong to this unit as well. Extends northwards to around Fauresmith in the northwest and to the Wepener District in the northeast. Altitude 1 120–1 680 m.

Vegetation & Landscape Features Slopes of koppies, butts and tafelbergs covered by two-layered karroid shrubland. The lower (closed-canopy) layer is dominated by dwarf small-leaved shrubs and, especially in precipitation-rich years, also by abundant grasses, while the upper (loose canopy) layer is dominated by tall shrubs, namely *Rhus erosa*, *R. burchellii*, *R. ciliata*, *Euclea crispa* subsp. *ovata*, *Diospyros austro-africana* and *Olea europaea* subsp. *africana*.

Geology & Soils Dolerite koppies and sills embedded within Karoo Supergroup sediments. The dolerite dykes and sills are igneous intrusions that are the result of extensive volcanic activity, which accompanied the break-up of Gondwana in the Jurassic. In places the slopes of mesas and butts carrying this vegetation type have a mixed geology where dolerites occur together with sandstones and mudstones of the Ecca and Beaufort Groups. Fb land type covers almost 60% of the area, followed by Ib.

Climate Due to the large extent of the area, the rainfall pattern differs slightly from west to east. Seasonal summer rainfall prevails when the patches are found embedded within other units of the Grassland Biome, but the southern and southwestern regions show hints of bimodal climate patterns typical of the Nama-Karoo. Far more importantly, despite an overall MAP of almost 400 mm, MAP ranges from about 280 mm in the west (De Aar) to more than double, 580 mm, in the east (Edenburg). Much of the rainfall is of convectional origin. MAT 15°C. See also climate diagram for Gh 4 Besemkaree Koppies Shrubland (Figure 8.23).

Important Taxa Small Trees: *Cussonia paniculata*, *Ziziphus mucronata*. Tall Shrubs: *Diospyros austro-africana* (d), *Euclea crispa* subsp. *ovata* (d), *Olea europaea* subsp. *africana* (d), *Rhus burchellii* (d), *R. ciliata* (d), *R. erosa* (d), *Buddleja saligna*, *Diospyros lycioides* subsp. *lycioides*, *Ehretia rigida*, *Grewia occidentalis*, *Gymnosporia polyacantha*, *Tarchonanthus minor*. Low Shrubs: *Asparagus suaveolens* (d), *Chrysocoma ciliata* (d), *Amphiglossa triflora*, *Aptosimum elongatum*, *Asparagus striatus*, *Diospyros pallens*, *Eriocephalus ericoides*, *E. spinescens*, *Euryops empetrifolius*, *Felicia filifolia* subsp. *filifolia*, *F. muricata*, *Helichrysum dregeanum*, *H. lucilioides*, *Hermannia multiflora*, *H. vestita*, *Lantana rugosa*, *Limeum aethiopicum*, *Lycium cinereum*, *Melolobium candicans*, *M. microphyllum*, *Nenax microphylla*, *Pegolettia retrofracta*, *Pentzia globosa*, *Rhigozum obovatum*, *Selago saxatilis*, *Stachys linearis*, *S. rugosa*, *Sutera halimifolia*, *Wahlenbergia albens*. Succulent Shrubs: *Aloe broomii*, *Chasmatophyllum musculinum*, *C. verdoorniae*, *Cotyledon orbiculata* var. *dactylopsis*, *Pachypodium succulentum*. Graminoids: *Aristida adscensionis* (d), *A. congesta* (d), *A. diffusa* (d), *Cenchrus ciliaris* (d), *Cymbopogon caesius* (d), *Cynodon incompletus* (d), *Digitaria eriantha* (d), *Eragrostis curvula* (d), *E. lehmanniana* (d), *Heteropogon contortus* (d), *Setaria lindenbergiana* (d), *Themeda triandra* (d), *Tragus koelerioides* (d), *Cymbopogon pospischilii*, *Enneapogon scoparius*, *Eragrostis chloromelas*, *E. obtusa*, *Eustachys paspaloides*, *Fingerhuthia africana*, *Hyparrhenia hirta*, *Sporobolus fimbriatus*. Herbs: *Convolvulus sagittatus*, *Dianthus caespitosus* subsp. *caespitosus*, *Gazania krebsiana* subsp. *krebsiana*, *Hibiscus pusillus*, *Indigofera alternans*, *I. rhytidocarpa*, *Lepidium africanum* subsp. *africanum*, *Pollichia campestris*. Herbaceous Climber: *Argyrolobium lanceolatum*. Geophytic Herbs: *Albuca setosa*, *Asplenium cordatum*, *Cheilanthes bergiana*, *C. eckloniana*, *Freesia andersoniae*, *Haemanthus humilis* subsp. *humilis*, *Oxalis depressa*, *Pellaea calomelanos*. Succulent Herbs: *Aloe grandidentata*, *Crassula nudicaulis*, *Duvalia caespitosa*, *Euphorbia pulvinata*, *Huernia piersii*, *Stapelia grandiflora*, *S. olivacea*, *Tridentea gemmiflora*.

Endemic Taxa Small Tree: *Cussonia* sp. nov. (*P.J. du Preez 3666* BLFU). Succulent Shrubs: *Euphorbia crassipes*, *Neohenricia sibbettii*, *N. spiculata*.

Conservation Least threatened because largely excluded from intensive agricultural activities. Target 28%. About 5% statutorily conserved in the Rolfontein, Tussen Die Riviere, Oviston, Gariep Dam, Caledon and Kalkfontein Dam Nature Reserves. In addition a small patch is also protected in the private Vulture Conservation Area. About 3% of the area has been lost through building of dams (Bethulie, Egmont, Gariep, Kalkfontein, Vanderkloof and Welbedacht Dams). Erosion moderate (68%), high (20%) and low (10%).

Remarks The diversity of the shrub component is lower than in the Gm 5 Basotho Montane Shrubland—a similar shrubland unit occurring on the Drakensberg foothills. The density of shrubs marking the slopes of the koppies decreases along a northeast-southwest gradient. On the southern edges of the distribution area of this unit, shrubs retreat to drainage lines and onto the base of dolerite caps, while the slopes themselves remain covered by dwarf shrublands of the NKu 4 Eastern Upper Karoo. In the northeastern areas which receive a higher rainfall, the sheltered sites have larger trees such as *Rhus lancea* and *Celtis africana*.

References Acocks (1953, 1988), Werger (1973a, b, 1983), Jooste (1989), Du Preez (1991), Du Preez & Bredenkamp (1991), Malan (1993, 1998), Malan et al. (1994, 1998, 1999), Lloyd & Badenhorst (1995, 1996), Müller (2002), Botha (2003).

Gh 5 Bloemfontein Dry Grassland

VT 36 False Upper Karoo (60%) (Acocks 1953). LR 52 Eastern Mixed Nama Karoo (58%) (Low & Rebelo 1996).

Distribution Free State Province: South-central part of the province, with Bloemfontein more or less centrally. Extending from Petrusburg in the west to the Rustfontein Dam in the east and from Reddersburg in the south to the Soetdoring Nature Reserve in the north. Altitude 1 200–1 480 m, but mostly 1 320–1 420 m.

Vegetation & Landscape Features Slightly undulating bottomland landscape covered with tall, dense grassland alternating with patches of karroid scrub occurring especially over calcrete.

L. Mucina

Figure 8.28 Gh 5 Bloemfontein Dry Grassland: Typical central Free State grasslands (dominated by *Themeda triandra* in well-managed facies) along the N1 road south of Leeukop near Bloemfontein.

Geology & Soils Sedimentary mudstones and layers of sandstone mainly of the Adelaide Subgroup (Beaufort Group, Karoo Supergroup). Volksrust Formation mudstones of the Ecca Group (also Karoo Supergroup) dominate the western part of the area. Deep (>300 mm) layer of red sand (aeolian origin) covers the more clayey B-horizons. Soil forms such as arable Hutton, Bainsvlei and Bloemdal occur here and are typical of the Ca land type. The Ea land type has shallow gravelly soils underlain by dolerite sills. Ca and Ae land types are nearly equally represented.

Climate Summer-rainfall region, with MAP around 450 mm. Most of the rainfall is of convectional origin and peaks in late summer. Overall MAT is within warm-temperate ranges (nearly 16°C), with high incidence of frost in winter. See also climate diagram for Gh 5 Bloemfontein Dry Grassland (Figure 8.23).

Important Taxa Graminoids: *Anthephora pubescens* (d), *Aristida congesta* (d), *A. diffusa* (d), *Cynodon dactylon* (d), *Digitaria argyrograpta* (d), *Elionurus muticus* (d), *Eragrostis chloromelas* (d), *E. lehmanniana* (d), *E. obtusa* (d), *E. plana* (d), *E. superba* (d), *E. trichophora* (d), *Heteropogon contortus* (d), *Panicum stapfianum* (d), *Setaria sphacelata* (d), *Themeda triandra* (d), *Tragus koelerioides* (d), *Aristida stipitata* subsp. *graciliflora*, *Chloris virgata*, *Cymbopogon pospischilii*, *Pogonarthria squarrosa*, *Sporobolus fimbriatus*, *Trichoneura grandiglumis*, *Triraphis andropogonoides*. Herbs: *Selago densiflora* (d), *Berkheya onopordifolia* var. *onopordifolia*, *Blepharis integrifolia* var. *clarkei*, *Chamaesyce inaequilatera*, *Commelina africana*, *Dicoma macrocephala*, *Gazania krebsiana* subsp. *krebsiana*, *Geigeria ornativa*, *Harpagophytum procumbens*, *Helichrysum caespititium*, *Heliotropium ciliatum*, *Hermannia comosa*, *H. tomentosa*, *Indigofera alternans*, *Lactuca dregeana*, *Lotononis listii*, *Monsonia burkeana*, *Nolletia ciliaris*, *Pollichia campestris*. Geophytic Herbs: *Oxalis depressa* (d), *Haemanthus humilis* subsp. *humilis*. Succulent Herb: *Tripteris aghillana* var. *integrifolia*. Low Shrubs: *Chrysocoma ciliata* (d), *Felicia filifolia* subsp. *filifolia* (d), *Pentzia globosa* (d), *P. incana* (d), *Amphiglossa triflora*, *Anthospermum rigidum* subsp. *pumilum*, *Asparagus striatus*, *Felicia muricata*, *Gnidia polycephala*, *Helichrysum dregeanum*, *Nenax microphylla*, *Osteospermum leptolobum*, *Polygala hottentotta*, *Selago saxatilis*. Succulent Shrub: *Hertia pallens*.

Conservation Endangered. Target 24%. Only a small portion is statutorily conserved in the Soetdoring Nature Reserve. More than 40% already transformed, e.g. for crop production (mainly Ae and Ca land types) as well as by urban (and related) development (the largest part of this vegetation unit on the Ae land type is situated in the Genl De Wet military training area, west of Bloemfontein). Especially those grasslands on shallow gravelly soils as well as the low-lying areas on clayey soils are prone to karoo-bush encroachment when overgrazed. Erosion low (50%), very low (37%) or moderate (13%).

Remarks This unit differs from the southern and western units (Gh 3 Xhariep Karroid Grassland, Gh 2 Aliwal North Dry Grassland and NKu 3 Northern Upper Karoo) in that a thicker sandy layer (>300 mm) covers the calcrete subsoils. This limits the distribution of dwarf karroid shrub species to a large extent. The deeper sandy soils also provide suitable habitat for psammophytes such as *Harpagophytum procumbens* and *Dicoma macrocephala*. The units to the east and north (Gh 6 Central Free State Grassland, Gh 9 Western Free State Clay Grassland) receive relatively higher rainfall, which supports denser grasslands.

References Acocks (1953, 1988), Malan (1993, 1998), Malan et al. (1995), Dingaan (1999).

Gh 6 Central Free State Grassland

VT 49 Transitional *Cymbopogon–Themeda* Veld (50%) (Acocks 1953). LR 39 Moist Cool Highveld Grassland (78%) (Low & Rebelo 1996).

Distribution Free State Province and marginally into Gauteng Province: A broad zone from around Sasolburg in the north to Dewetsdorp in the south. Other major settlements located within this unit include Kroonstad, Ventersburg, Steynsrus, Winburg, Lindley and Edenville. Altitude 1 300–1 640 m, most of the area at 1 400–1 460 m.

Vegetation & Landscape Features Undulating plains supporting short grassland, in natural condition dominated by *Themeda triandra* while *Eragrostis curvula* and *E. chloromelas* become dominant in degraded habitats. Dwarf karoo bushes establish in severely degraded clayey bottomlands. Overgrazed and trampled low-lying areas with heavy clayey soils are prone to *Acacia karroo* encroachment.

Geology & Soils Sedimentary mudstones and sandstone mainly of the Adelaide Subgroup (Beaufort Group, Karoo Supergroup)

as well as those of the Ecca Group (Karoo Supergroup) found in the extreme northern section of this grassland, giving rise to vertic, melanic and red soils (typical forms are Arcadia, Bonheim, Kroonstad, Valsrivier and Rensburg)—typical of Dc land type (dominating the landscape). The less common intrusive dolerites of the Jurassic Karoo Dolerite Suite support dry clayey soils typical of the Ea land type.

Climate Summer-rainfall seasonal precipitation region, with MAP 560 mm. Much of the rainfall is of convectional origin and peaks in December to January. The overall MAT around 15°C. Incidence of frost relatively high (43 days on average). See also climate diagram for Gh 6 Central Free State Grassland (Figure 8.23).

P.J. du Preez

Figure 8.29 Gh 7 Winburg Grassy Shrubland: An *Olea europaea* subsp. *africana* shrubland on slopes of a dolerite koppie north of Bloemfontein (central Free State).

Important Taxa Graminoids: *Aristida adscensionis* (d), *A. congesta* (d), *Cynodon dactylon* (d), *Eragrostis chloromelas* (d), *E. curvula* (d), *E. plana* (d), *Panicum coloratum* (d), *Setaria sphacelata* (d), *Themeda triandra* (d), *Tragus koelerioides* (d), *Agrostis lachnantha*, *Andropogon appendiculatus*, *Aristida bipartita*, *A. canescens*, *Cymbopogon pospischilii*, *Cynodon transvaalensis*, *Digitaria argyrograpta*, *Elionurus muticus*, *Eragrostis lehmanniana*, *E. micrantha*, *E. obtusa*, *E. racemosa*, *E. trichophora*, *Heteropogon contortus*, *Microchloa caffra*, *Setaria incrassata*, *Sporobolus discosporus*. Herbs: *Berkheya onopordifolia* var. *onopordifolia*, *Chamaesyce inaequilatera*, *Conyza pinnata*, *Crabbea acaulis*, *Geigeria aspera* var. *aspera*, *Hermannia depressa*, *Hibiscus pusillus*, *Pseudognaphalium luteo-album*, *Salvia stenophylla*, *Selago densiflora*, *Sonchus dregeanus*. Geophytic Herbs: *Oxalis depressa*, *Raphionacme dyeri*. Succulent Herb: *Tripteris aghillana* var. *integrifolia*. Low Shrubs: *Felicia muricata* (d), *Anthospermum rigidum* subsp. *pumilum*, *Helichrysum dregeanum*, *Melolobium candicans*, *Pentzia globosa*.

Conservation Vulnerable. Target 24%. Only small portions enjoy statutory conservation (Willem Pretorius, Rustfontein and Koppies Dam Nature Reserves) as well as some protection in private nature reserves. Almost a quarter of the area has been transformed either for cultivation or by building of dams (Allemanskraal, Erfenis, Groothoek, Koppies, Kroonstad, Lace Mine, Rustfontein and Weltevrede). No serious infestation by alien flora has been observed, but encroachment of dwarf karoo shrubs becomes a problem in the degraded southern parts of this vegetation unit. Erosion low (45%), moderate (30%) or very low (20%).

Remarks On cool moist southern slopes, elements of the Gm 4 Eastern Free State Sandy Grassland are notable. Stands of Gh 7 Winburg Grassy Shrubland are present on outcrops (dykes and sills) of dolerite embedded within this grassland.

References Acocks (1953, 1988), Müller (1986), Du Preez & Bredenkamp (1991), Fuls et al. (1992), Müller (2002).

Gh 7 Winburg Grassy Shrubland

VT 50 Dry *Cymbopogon–Themeda* Veld (63%) (Acocks 1953). LR 37 Dry Sandy Highveld Grassland (63%) (Low & Rebelo 1996).

Distribution Free State Province: Series of larger patches between Trompsburg through Bloemfontein and Winburg to Ventersburg. Altitude 1 300–1 660 m, mainly 1 360–1 440 m.

Vegetation & Landscape Features Solitary hills, slopes and escarpments of mesas creating a mosaic of habitats ranging from open grassland to shrubland. Tall shrubs and sometimes small trees are sheltered against frequent periods of frost during the winter months and regular veld fires in late winter to early spring. The medium-height evergreen shrublands are dominated by a combination of *Olea europaea* subsp. *africana*, *Euclea crispa* subsp. *crispa*, *Gymnosporia buxifolia*, *Diospyros lycioides*, *Rhus burchellii*, *R. ciliata*, *R. erosa* (mainly in the south), *Clutia pulchella* and *Grewia occidentalis*. Trees such as *R. lancea*, *Celtis africana* and *Ziziphus mucronata* are found in more deeply incised drainage lines.

Geology & Soils Extensive dolerite sills forming ridges, plateaus and slopes of koppies, and small escarpments marking the erosion terraces. The sills cover alternating layers of mudstone and sandstone of sedimentary origin (Adelaide Subgroup of the Beaufort Group). Prominent soil forms are the stony Mispah and gravel-rich Glenrosa derived from Jurassic dolerite. Dominating land type Ea, with Dc also present in places.

Climate Summer-rainfall region, with MAP around 500 mm. Much of the rainfall is of convectional origin. Overall MAT is slightly higher than 15°C, with more than 40 days of frost in winter. See also climate diagram for Gh 7 Winburg Grassy Shrubland (Figure 8.23).

Important Taxa Small Trees: *Acacia karroo*, *Celtis africana*, *Cussonia paniculata*, *Pittosporum viridiflorum*, *Rhus lancea*, *Scolopia zeyheri*, *Ziziphus mucronata*. Tall Shrubs: *Buddleja saligna* (d), *Euclea crispa* subsp. *ovata* (d), *Gymnosporia polyacantha* (d), *Olea europaea* subsp. *africana* (d), *Rhus burchellii* (d), *R. erosa* (d), *Diospyros lycioides* subsp. *lycioides*, *Grewia occidentalis*, *Gymnosporia buxifolia*, *Tarchonanthus camphoratus*. Low Shrubs: *Helichrysum dregeanum* (d), *Pentzia globosa* (d), *Anthospermum rigidum* subsp. *pumilum*, *Asparagus cooperi*, *A. laricinus*, *Berkheya annectens*, *Chrysocoma ciliata*, *Clutia pulchella*, *Euryops empetrifolius, Felicia filifolia* subsp. *filifolia*, *F. muricata*, *Nenax microphylla*, *Osyris lanceolata*, *Rosenia humilis*, *Selago saxatilis*, *Solanum tomentosum* var. *coccineum*. Graminoids: *Aristida adscensionis* (d), *A. congesta* (d), *A. diffusa* (d), *Cymbopogon pospischilii* (d), *Cynodon dactylon* (d), *C. incompletus* (d), *Eragrostis chloromelas* (d), *E. lehmanniana* (d), *E. micrantha* (d), *E. obtusa* (d), *E. trichophora* (d), *Eustachys*

paspaloides (d), *Heteropogon contortus* (d), *Panicum stapfianum* (d), *Setaria lindenbergiana* (d), *S. sphacelata* (d), *Sporobolus fimbriatus* (d), *Themeda triandra* (d), *Tragus koelerioides* (d), *Digitaria argyrograpta*, *Elionurus muticus*, *Enneapogon scoparius*, *Eragrostis plana*, *E. superba*, *Tragus berteronianus*, *T. racemosus*, *Triraphis andropogonoides*. Herbs: *Berkheya onopordifolia* var. *onopordifolia*, *Hermannia coccocarpa*, *Indigofera alternans*, *Mohria caffrorum*, *Pupalia lappacea*, *Salvia repens*. Geophytic Herbs: *Oxalis corniculata*, *O. depressa*. Succulent Herb: *Crassula lanceolata*.

Conservation Least threatened. Target 28%. Almost 2% statutorily conserved in the Willem Pretorius Nature Reserve. More than 10% transformed for cultivation and by urban sprawl. Erosion low (57%), very low (24%) and moderate (18%).

Remarks The vegetation of this unit differs considerably in species composition and structure, from analogous shrubland typical of koppies south and southwest of Bloemfontein (Gh 4 Besemkaree Koppies Shrubland), in having some afromontane elements and a more mesic character. Dolerite hills along the Sand River as well as those found in the Willem Pretorius Nature Reserve are home to some sourveld shrub species, such as *Elaeodendron transvaalense*, *Scolopia zeyheri*, *Rhus leptodictya* and *Helinus integrifolius*.

References Acocks (1953, 1988), Du Preez (1979), Roussouw (1983), Müller (1986), Du Preez (1991), Malan (1993, 1998), Malan et al. (1994, 1995), Dingaan (1999), Müller (2002).

Gh 8 Bloemfontein Karroid Shrubland

VT 50 Dry *Cymbopogon–Themeda* Veld (47%), VT 49 Transitional *Cymbopogon–Themeda* Veld, (35%) (Acocks 1953). LR 37 Dry Sandy Highveld Grassland (64%) (Low & Rebelo 1996).

Distribution Free State and Mpumalanga (only in the southwest) Provinces: An archipelago of isolated patches found on koppies, butts and ridges embedded mainly within dry highveld grasslands in the region extending over large distances between Bloemfontein in the southwest, Verkeerdevlei and Lindley in the southeast, Standerton in the northeast as well as Heilbron and Bultfontein in the northwest. Altitude 1 320–1 840 m, mostly 1 400–1 440 m.

Vegetation & Landscape Features Plateaus or slightly sloping flanks of dolerite outcrops supporting low shrubland dominated by dwarf small-leaved karroid and succulent shrubs. Grasses are restricted to depressions and crevices filled with fine soils. Remarkable is the presence of abundant geophytic herbs. Solitary shrubs or small shrub groups with *Diospyros austro-africana*, *Euclea crispa* subsp. *ovata*, *Rhus burchellii*, *R. ciliata* and *R. erosa* are occasionally present, especially in habitats where root penetration into deeper crevices is possible.

Geology & Soils Restricted to Jurassic dolerite intrusions (sills) embedded within sediments of the Adelaide Subgroup (Beaufort Group, Karoo Supergroup). Typical feature of this habitat is a shallow (only 1–5 cm thick) layer of sand of aeolian origin that overlies sheets of dolerite. Dominant land type is Ea, followed by Dc and Fa (the last-named on the Karoo Supergroup sediments).

Climate Summer-rainfall area, with MAP close to 570 mm and from 550 mm (Bloemfontein) to 650 mm (Standerton). Much of the rainfall is of convectional origin. MAT 15°C, indicating a warm-temperate climatic regime. Winters can be very cold and frost incidence is high (40 days). See also climate diagram for Gh 8 Bloemfontein Karroid Shrubland (Figure 8.23).

Important Taxa Tall Shrubs: *Diospyros austro-africana*, *Euclea crispa* subsp. *ovata*, *Rhus burchellii*, *R. erosa*, *R. tridactyla*. Low Shrubs: *Eriocephalus ericoides* (d), *Euryops empetrifolius* (d), *Anthospermum rigidum* subsp. *pumilum*, *Asparagus suaveolens*, *Felicia muricata*, *Helichrysum dregeanum*, *Heliophila suavissima*, *Jamesbrittenia pristisepala*, *Nenax microphylla*, *Pentzia globosa*, *Phyllanthus parvulus*, *Selago albida*. Succulent Shrubs: *Chasmatophyllum musculinum* (d), *Euphorbia mauritanica* (d), *Ruschia spinosa* (d), *Stomatium mustellinum* (d), *Cotyledon orbiculata* var. *dactylopsis*, *Euphorbia rectirama*, *Kalanchoe paniculata*, *Othonna protecta*, *Pachypodium succulentum*, *Ruschia hamata*, *R. unidens*, *Sarcocaulon salmoniflorum*, *Stapelia grandiflora*. Succulent Woody Climber: *Sarcostemma viminale*. Graminoids: *Aristida diffusa* (d), *Eragrostis nindensis* (d), *Heteropogon contortus* (d), *Oropetium capense* (d), *Aristida adscensionis*, *A. congesta*, *Cymbopogon caesius*, *C. pospischilii*, *Cyperus rupestris* var. *rupestris*, *Digitaria eriantha*, *Enneapogon scoparius*, *Eragrostis chloromelas*, *E. obtusa*, *E. superba*, *E. trichophora*, *Eustachys paspaloides*, *Melinis repens* subsp. *repens*, *Microchloa caffra*, *Themeda triandra*, *Tragus koelerioides*, *T. racemosus*. Herbs: *Berkheya onopordifolia* var. *onopordifolia*, *B. rigida*, *Chamaesyce inaequilatera*, *Commelina africana*, *Gazania linearis* var. *linearis*, *Geigeria aspera* var. *aspera*, *G. filifolia*, *Hermannia coccocarpa*. Geophytic Herbs: *Cheilanthes ecklioniana* (d), *Albuca setosa*, *Dipcadi ciliare*, *D. viride*, *Nerine laticoma*, *Pellaea calomelanos*, *Trachyandra saltii*. Succulent Herbs: *Senecio radicans* (d), *Adromischus trigynus*, *Aloe grandidentata*, *Anacampseros telephiastrum*, *Avonia ustulata*, *Crassula nudicaulis*, *Duvalia corderoyi*, *Orbea cooperi*, *Orbeopsis lutea*, *Tripteris aghillana* var. *integrifolia*.

Endemic Taxon Geophytic Herb: *Brachystelma glenense*.

P.J. du Preez

Figure 8.30 Gh 8 Bloemfontein Karroid Shrubland: Dolerite rocky sheet with pockets of shallow soil supporting low grassy karroid shrubland with prominent succulent shrubs, xerophilous ferns, bulbous herbs and the prominent grass *Eragrostis nindensis*; near the entrance to the Free State National Botanical Garden in Bloemfontein (central Free State).

Conservation Some sites of this vegetation are exposed to considerable urban developmental pressures, especially within the borders of the Mangaung Municipality (see Haasbroek 2003). Target 28%. None conserved in statutory conservation areas, but small portions are found on the premises of the Free State National Botanical Garden in Bloemfontein. About 10% already transformed, mainly by cultivation. Erosion low (66%) and very low (24%).

J.P.H. Acocks

Figure 8.31 Gh 9 Western Free State Clay Grassland: Dry grassland with abundant karroid elements near Uitkyk (Boshof District, Free State) as photographed in the 1960s.

Remarks Potts & Tidmarsh (1937) were the first to describe this vegetation and to recognise the fact that it is a unique 'island' of succulent-dominated karroid shrub community in the Grassland Biome. They named the identified units *Mesembryanthemum spinosum–Euphorbia mauritanica* Scrub, and *Euryops sulcatus–Euphorbia mauritanica* Scrub (Potts & Tidmarsh 1937). Dingaan & Du Preez (2002) and Haasbroek (2003) recently surveyed this unique vegetation. Although there is a strong affinity to some of the vegetation units of the arid west (Upper Karoo Hardeveld, Western Upper Karoo and Northern Upper Karoo), it also has a notable grass component including *Oropetium capense*, *Eragrostis nindensis*, *Aristida congesta*, *E. trichophora*, *E. lehmanniana*, *Heteropogon contortus*, *Themeda triandra* and *Digitaria eriantha*. We suggest that the occurrence of a karroid shrubland within highveld grasslands relates to physiological drought due to shallow soils, high runoff, high evaporation rates and impeded infiltration of rainwater. These factors create a soil-controlled microhabitat for vegetation, which might be considered a relict of drier (and presumably colder) past climatic periods.

References Potts & Tidmarsh (1937), Acocks (1953, 1988), Mostert (1958), Müller (1986), Du Preez & Bredenkamp (1991), Dingaan (1996), Dingaan & Du Preez (2002), Haasbroek (2003).

Gh 9 Western Free State Clay Grassland

VT 50 Dry *Cymbopogon–Themeda* Veld (52%) (Acocks 1953). LR 37 Dry Sandy Highveld Grassland (81%) (Low & Rebelo 1996).

Distribution Free State Province: Region covering part of the western Bloemfontein District (south), Boshof (southwest), Hertzogville (west), Wesselsbron (north) and Brandfort (east) and consisting of three main areas, of which the southern and middle sections are separated by a slightly elevated area (dolerite hills) between Hertzogville, Boshof and Soutpan. The Vet River Valley separates the middle and northern sections and all three sections are separated from one another by belts of Gh 10 Vaal-Vet Sandy Grassland. Altitude 1 200–1 420 m.

Vegetation & Landscape Features Restricted to flat bottomlands which support dry, species-poor grassland with a high number of salt pans (playas) embedded. Dwarf karoo shrublands surround the playas in disturbed habitats.

Geology & Soils Deposits of sandstone, mudstone and shale (Volksrust Formation, Ecca Group) underlie extensive areas of flat to undulating plains, interrupted by dolerite sills in places. No rivers or streams drain away from these plains, and all the water drains into the numerous playas (pans)—a unique feature of this landscape. Dry, clayey, duplex soils typical of land types Da, Db and Dc. Fc land type also occurs.

Climate Seasonal rainfall concentrated from November–March (overall MAP 450 mm). Cool temperate regime with MAT 16–17°C. Occurrence of frost frequent. See also climate diagram for Gh 9 Western Free State Clay Grassland (Figure 8.23).

Important Taxa Graminoids: *Aristida adscensionis* (d), *A. bipartita* (d), *Cynodon dactylon* (d), *Eragrostis chloromelas* (d), *E. lehmanniana* (d), *Panicum coloratum* (d), *Themeda triandra* (d), *Aristida congesta*, *Cymbopogon pospischilii*, *Digitaria eriantha*, *Eragrostis bicolor*, *E. curvula*, *E. micrantha*, *E. obtusa*, *E. plana*, *E. superba*, *E. trichophora*, *Heteropogon contortus*, *Setaria nigrirostris*, *Tragus berteronianus*, *T. koelerioides*, *T. racemosus*. Herbs: *Berkheya onopordifolia* var. *onopordifolia*, *Chamaesyce inaequilatera*, *Gnaphalium declinatum*, *Indigofera alternans*, *Kohautia cynanchica*, *Nidorella microcephala*, *Platycarpha parvifolia*, *Salvia stenophylla*, *Selago paniculata*, *Stachys spathulata*. Geophytic Herbs: *Bulbine narcissifolia*, *Oxalis depressa*. Succulent Herb: *Tripteris aghillana* var. *integrifolia*. Low Shrubs: *Lycium cinereum* (d), *Pentzia globosa* (d), *Amphiglossa triflora*, *Aptosimum elongatum*, *Berkheya annectens*, *Felicia filifolia* subsp. *filifolia*, *F. muricata*, *Gnidia polycephala*, *Helichrysum dregeanum*, *Melolobium candicans*, *Nenax microphylla*, *Rosenia humilis*, *Selago saxatilis*. Succulent Shrub: *Hertia pallens*.

Conservation Least threatened. Target 24%. None conserved in statutory conservation areas. Almost 20% already transformed for maize and wheat cultivation. A species of *Prosopis* appears as occasional invasive alien. Erosion very low (38%), low (30%) and moderate (28%).

Remarks The vegetation of the salt pans embedded within this grassland unit is treated as a separate vegetation unit AZi 10 Highveld Salt Pans.

References Kooij (1990), Kooij et al. (1990a).

Gh 10 Vaal-Vet Sandy Grassland

VT 50 Dry *Cymbopogon–Themeda* Veld (47%), VT 48 *Cymbopogon–Themeda* Veld (sandy) (24%) (Acocks 1953). LR 37 Dry Sandy Highveld Grassland (74%) (Low & Rebelo 1996).

Distribution North-West and Free State Provinces: South of Lichtenburg and Ventersdorp, stretching southwards to

Klerksdorp, Leeudoringstad, Bothaville and to the Brandfort area north of Bloemfontein. Altitude 1 220–1 560 m, generally 1 260–1 360 m.

Vegetation & Landscape Features Plains-dominated landscape with some scattered, slightly irregular undulating plains and hills. Mainly low-tussock grasslands with an abundant karroid element. Dominance of *Themeda triandra* is an important feature of this vegetation unit. Locally low cover of *T. triandra* and the associated increase in *Elionurus muticus*, *Cymbopogon pospischilii* and *Aristida congesta* is attributed to heavy grazing and/or erratic rainfall.

Geology & Soils Aeolian and colluvial sand overlying sandstone, mudstone and shale of the Karoo Supergroup (mostly the Ecca Group) as well as older Ventersdorp Supergroup andesite and basement gneiss in the north. Soil forms are mostly Avalon, Westleigh and Clovelly. Dominant land type Bd, closely followed by Bc, Ae and Ba.

Climate Warm-temperate, summer-rainfall climate, with overall MAP of 530 mm. High summer temperatures. Severe frost (37 days per year on average) occurs in winter. See also climate diagram for Gh 12 Vaal-Vet Sandy Grassland (Figure 8.23).

Important Taxa Graminoids: *Anthephora pubescens* (d), *Aristida congesta* (d), *Chloris virgata* (d), *Cymbopogon caesius* (d), *Cynodon dactylon* (d), *Digitaria argyrograpta* (d), *Elionurus muticus* (d), *Eragrostis chloromelas* (d), *E. lehmanniana* (d), *E. plana* (d), *E. trichophora* (d), *Heteropogon contortus* (d), *Panicum gilvum* (d), *Setaria sphacelata* (d), *Themeda triandra* (d), *Tragus berteronianus* (d), *Brachiaria serrata*, *Cymbopogon pospischilii*, *Digitaria eriantha*, *Eragrostis curvula*, *E. obtusa*, *E. superba*, *Panicum coloratum*, *Pogonarthria squarrosa*, *Trichoneura grandiglumis*, *Triraphis andropogonoides*. Herbs: *Stachys spathulata* (d), *Barleria macrostegia*, *Berkheya onopordifolia* var. *onopordifolia*, *Chamaesyce inaequilatera*, *Geigeria aspera* var. *aspera*, *Helichrysum caespititium*, *Hermannia depressa*, *Hibiscus pusillus*, *Monsonia burkeana*, *Rhynchosia adenodes*, *Selago densiflora*, *Vernonia oligocephala*. Geophytic Herbs: *Bulbine narcissifolia*, *Ledebouria marginata*. Succulent Herb: *Tripteris aghillana* var. *integrifolia*. Low Shrubs: *Felicia muricata* (d), *Pentzia globosa* (d), *Anthospermum rigidum* subsp. *pumilum*, *Helichrysum dregeanum*, *H. paronychioides*, *Ziziphus zeyheriana*.

Endemic Taxon Herb: *Lessertia phillipsiana*.

Conservation Endangered. Target 24%. Only 0.3% statutorily conserved in the Bloemhof Dam, Schoonspruit, Sandveld, Faan Meintjies, Wolwespruit and Soetdoring Nature Reserves. More than 63% transformed for cultivation (ploughed for commercial crops) and the rest under strong grazing pressure from cattle and sheep. Erosion very low (85.3%) and low (11%).

References Louw (1951), Morris (1973, 1976), Bredenkamp & Bezuidenhout (1990), Kooij et al. (1990b, 1992), Bezuidenhout et al. (1994a).

Gh 11 Vredefort Dome Granite Grassland

VT 48 *Cymbopogon–Themeda* Veld (sandy) (49%), VT 61 Bankenveld (25%) (Acocks 1953). LR 34 Rocky Highveld Grassland (95%) (Low & Rebelo 1996).

Distribution Free State and North-West Provinces: Central portion of the Vredefort Dome around Parys and Vredefort. Altitude 1 340–1 520 m.

Vegetation & Landscape Features Slightly undulating plains with mainly short, *Themeda triandra*-dominated grassland, though mostly grazed and often degraded. One of the most scenic landscapes of the Highveld, with the Vaal River cutting through the mountainous landscape (Savanna Biome) of the Vredefort Dome. Big boulders of granite are conspicuous in the area, creating microhabitats for a diversity of plant species.

Geology & Soils Granite and gneiss at the core of the Vredefort Dome underlie this area and includes the Inlandsee Gneiss. Various soil types including the Hutton, Mispah and Avalon forms, representing plinthic soils, which can be dystrophic and/or mesotrophic (Ba land type) or eutrophic (Bc land type). Red soils are generally widespread.

Climate Warm-temperate, summer-rainfall region, with overall MAP of 594 mm. Summer temperatures are high. Severe frost (38 days per year on average) occurs in winter. See also climate diagram for Gh 11 Vredefort Dome Granite Grassland (Figure 8.23).

Important Taxa Graminoids: *Aristida congesta* (d), *Chloris virgata* (d), *Cynodon dactylon* (d), *Digitaria eriantha* (d), *Elionurus muticus* (d), *Eragrostis biflora* (d), *E. lehmanniana* (d), *E. trichophora* (d), *Setaria sphacelata* (d), *Themeda triandra* (d), *Tragus berteronianus* (d), *Aristida diffusa*, *Brachiaria serrata*, *Cymbopogon pospischilii*, *Eragrostis chloromelas*, *E. gummiflua*, *E. racemosa*, *E. superba*, *Heteropogon contortus*, *Hyparrhenia hirta*, *Trichoneura grandiglumis*, *Triraphis andropogonoides*. Herbs: *Barleria macrostegia*, *Berkheya setifera*, *Chamaesyce inaequilatera*, *Crabbea acaulis*, *Helichrysum rugulosum*, *Hermannia depressa*, *Ipomoea oblongata*, *I. obscura*, *Lepidium capense*, *Lotononis listii*, *Selago densiflora*, *Vernonia oligocephala*. Herbaceous Climber: *Rhynchosia totta*. Low Shrubs: *Felicia muricata* (d), *Anthospermum rigidum* subsp. *pumilum*, *Deverra burchellii*, *Polygala hottentotta*.

Conservation Endangered. Target 24%. None conserved in statutory conservation areas and almost half already transformed by cultivation (maize fields), by urban development or by road-building. Erosion is very low (96%).

S.S. Cilliers

Figure 8.32 Gh 11 Vredefort Dome Granite Grassland: *Melinis repens*-dominated grassland on granite (with a granite dome in the background) of the Vredefort Dome—an ancient large asteroid impact site near Potchefstroom (border region of the Free State and North-West Provinces).

Remarks Vredefort Dome is an interesting geological structure—a strongly eroded remnant of one of the largest impact craters of the world, about 2.2 billion years old.

References Du Preez (1986), Bezuidenhout et al. (1988, 1994c), Bredenkamp et al. (1989), Du Preez & Venter (1990), Bezuidenhout (1993).

Gh 12 Vaal Reefs Dolomite Sinkhole Woodland

VT 61 Western variation of the Bankenveld (55%), VT 48 *Cymbopogon–Themeda* veld (45%) (Acocks 1988). LR 34 Rocky Highveld Grassland (55%), LR 37 Dry Sandy Highveld Grassland (45%) (Low & Rebelo 1996).

Distribution North-West and Free State Provinces: Small area associated with the dolomite sinkholes in and around Stilfontein and Orkney (Vaal Reefs). The Vaal River forms the southern distribution limit of this vegetation unit. Altitude 1 280–1 380 m.

Vegetation & Landscape Features Slightly undulating landscape dissected by prominent rocky chert ridges and supporting a grassland-woodland vegetation complex. The most typical vegetation feature is the woodland, which occurs naturally in clumps around sinkholes, especially in places of dolomite outcrops.

Geology & Soils This area occurs almost exclusively on the dolomites of the Malmani Subgroup (Chuniespoort Group, Transvaal Supergroup), where underground dissolution of the rock causes sinkholes. More than 50% of the main soil types are relatively shallow (50–150 mm) and rocky, with the dominant soil forms Mispah, Glenrosa and shallow Hutton. The latter soils are associated with the Fa land type.

Climate Warm-temperate summer-rainfall region, with overall MAP around 560 mm. The summer temperatures are high. Severe frequent frost occurs in winter. See also climate diagram for Gh 12 Vaal Reefs Dolomite Sinkhole Woodland (Figure 8.23).

Important Taxa Small Trees: *Acacia erioloba* (d), *Celtis africana* (d), *Rhus lancea* (d), *Acacia caffra*, *A. karroo*, *A. robusta* subsp. *clavigera*. Tall Shrubs: *Diospyros lycioides* subsp. *lycioides* (d), *Ehretia rigida* (d), *Grewia flava* (d). Low Shrubs: *Asparagus suaveolens* (d), *Gymnosporia heterophylla* (d), *Pavonia burchellii* (d), *Sida dregei* (d), *Anthospermum hispidulum*, *Asparagus laricinus*, *Diospyros pallens*, *Felicia muricata*, *Indigofera heterotricha*, *Menodora africana*, *Phyllanthus incurvus*, *Triumfetta sonderi*, *Ziziphus zeyheriana*. Geoxylic Suffrutex: *Elephantorrhiza elephantina*. Woody Climber: *Asparagus africanus*. Graminoids: *Aristida congesta* (d), *Digitaria eriantha* (d), *Eragrostis biflora* (d), *E. curvula* (d), *Themeda triandra* (d), *Anthephora pubescens*, *Aristida canescens*, *Bewsia biflora*, *Brachiaria nigropedata*, *B. serrata*, *Chloris pycnothrix*, *Cymbopogon caesius*, *C. pospischilii*, *Cynodon dactylon*, *Cyperus margaritaceus*, *Diheteropogon amplectens*, *Elionurus muticus*, *Eragrostis chloromelas*, *E. lehmanniana*, *E. racemosa*, *E. superba*, *Eustachys paspaloides*, *Heteropogon contortus*, *Melinis repens* subsp. *repens*, *Panicum coloratum*, *Setaria sphacelata*, *Triraphis andropogonoides*. Herbs: *Commelina africana* (d), *Barleria macrostegia*, *Chamaecrista mimosoides*, *Chamaesyce inaequilatera*, *Chascanum hederaceum*, *Crabbea angustifolia*, *Cyanotis speciosa*, *Dicoma anomala*, *Hermannia depressa*, *Indigofera daleoides*, *I. torulosa* var. *angustiloba*, *Ipomoea obscura*, *Justicia anagalloides*, *Nidorella hottentotica*, *Osteospermum muricatum* subsp. *longiradiatum*, *Pollichia campestris*, *Pterodiscus speciosus*, *Vernonia oligocephala*. Geophytic Herb: *Albuca setosa*.

Conservation Vulnerable. Target 24%. Only a small patch conserved in the statutory conservation area of Sterkfontein Caves (part of the Cradle of Humankind World Heritage Site)—the legendary archaeological site associated with the discovery of a skeleton of *Australopithecus africanus*. The proposed 'Highveld National Park' is supposed to conserve a considerable area of this vegetation unit. Aesthetically this is one of the most scenic landscapes in the western Grassland Biome and certainly deserves high conservation priority. Almost a quarter has been transformed already—mainly by mining, cultivation, urban sprawl and road-building. The region of this unit contains possibly the highest concentration of mines of any other vegetation in South Africa. Erosion is generally very low.

Remarks The mapped extent of the dolomite sinkhole woodlands should be revisited at a more detailed scale than that offered by our current coverage. Clear separation (expressed in appropriate mapping coverage) between this unit and the adjacent Gh 15 Carletonville Dolomite Grassland is needed.

S.S. Cilliers

Figure 8.33 Gh 12 Vaal Reefs Dolomite Sinkhole Woodland: Isolated woodland patches composed of trees *Acacia erioloba* and *Celtis africana* and shrubs such as *Grewia flava*, *Ehretia rigida* and *Asparagus laricinus* indicating the position of a dolomite sinkhole, surrounded by tall grassland with *Themeda triandra* (near Potchefstroom, North-West Province).

References Louw (1951), Acocks (1953, 1988), Morris (1973), Coetzee (1974), Van Wyk (1983), Van Wyk & Bredenkamp (1986), Bezuidenhout (1993), Bezuidenhout et al. (1994b, c, e), Siebert & Siebert (2005).

Gh 13 Klerksdorp Thornveld

VT 50 Dry *Cymbopogon–Themeda* Veld (44%), VT 19 Sourish Mixed Bushveld (29%) (Acocks 1953). LR 37 Dry Sandy Highveld Grassland (70%) (Low & Rebelo 1996).

Distribution North-West Province: In two sets of patches, one in the Wolmaransstad, Ottosdal and Hartbeesfontein region, and the other from the Botsolano Game Park north of Mafikeng to the vicinity of Madibogo in the south. Altitude 1 260–1 580 m.

Vegetation & Landscape Features Plains or slightly irregular undulating plains with open to dense *Acacia karroo* bush clumps in dry grassland.

Geology & Soils Shale, slate and quartzite of the Pretoria Group with interlaid diabase sills and Hekpoort lava supporting relatively shallow and rocky soils (Glenrosa and Mispah forms), typical of the Fb land type. Equally represented are eutrophic red plinthic soils (Hutton form), derived mainly from a thick succession of volcanics and sediments of the Ventersdorp Supergroup (Bc land type). Bd and Ae of minor occurrence.

Climate Warm-temperate, summer-rainfall region, with overall MAP of 533 mm. Summer temperatures are high. Frequent frosts occur in winter. See also climate diagram for Gh 13 Klerksdorp Thornveld (Figure 8.23).

Important Taxa Small Trees: *Acacia karroo* (d), *A. caffra*, *Celtis africana*, *Rhus lancea*, *Ziziphus mucronata*. Tall Shrubs: *Acacia hebeclada*, *Diospyros lycioides* subsp. *lycioides*, *Ehretia rigida*, *Grewia flava*, *Gymnosporia buxifolia*, *Rhus pyroides*, *Tarchonanthus camphoratus*. Woody Climber: *Asparagus africanus*. Low Shrubs: *Asparagus laricinus* (d), *A. suaveolens* (d), *Felicia muricata* (d), *Anthospermum hispidulum*, *A. rigidum* subsp. *pumilum*, *Aptosimum elongatum*, *Gnidia capitata*, *Gomphocarpus fruticosus* subsp. *fruticosus*, *Helichrysum dregeanum*, *Leucas capensis*, *Pavonia burchellii*, *Pentzia globosa*, *Solanum supinum* var. *supinum*, *Triumfetta sonderi*, *Ziziphus zeyheriana*. Graminoids: *Aristida congesta* (d), *Cynodon dactylon* (d), *Eragrostis lehmanniana* (d), *E. trichophora* (d), *Microchloa caffra* (d), *Panicum coloratum* (d), *Sporobolus fimbriatus* (d), *Themeda triandra* (d), *Andropogon schirensis*, *Anthephora pubescens*, *Aristida junciformis* subsp. *galpinii*, *A. stipitata* subsp. *graciliflora*, *Brachiaria nigropedata*, *B. serrata*, *Bulbostylis burchellii*, *Cymbopogon pospischilii*, *Digitaria eriantha*, *Diheteropogon amplectens*, *Elionurus muticus*, *Eragrostis curvula*, *E. obtusa*, *E. racemosa*, *E. superba*, *Eustachys paspaloides*, *Heteropogon contortus*, *Setaria sphacelata*, *Sporobolus africanus*, *Tragus berteronianus*, *Trichoneura grandiglumis*, *Triraphis andropogonoides*. Herbs: *Acalypha angustata*, *Acanthospermum australe*, *Berkheya onopordifolia* var. *onopordifolia*, *B. setifera*, *Blepharis integrifolia* var. *clarkei*, *Chamaesyce inaequilatera*, *Chascanum adenostachyum*, *Dicoma macrocephala*, *Helichrysum nudifolium* var. *nudifolium*, *Hermannia lancifolia*, *Hibiscus pusillus*, *Justicia anagalloides*, *Lippia scaberrima*, *Nidorella microcephala*, *Nolletia ciliaris*, *Pollichia campestris*, *Rhynchosia adenodes*, *Salvia radula*, *Selago densiflora*, *Teucrium trifidum*, *Tolpis capensis*. Geophytic Herbs: *Bulbine narcissifolia*, *Ledebouria marginata*, *Ornithogalum tenuifolium* subsp. *tenuifolium*, *Raphionacme hirsuta*. Herbaceous Climber: *Rhynchosia venulosa*.

Conservation Vulnerable. Target 24%. Only about 2.5% conserved in the statutory Mafikeng Game Reserve, private Botsolano Game Park and Faan Meintjes Nature Reserve. Almost a third already transformed for cultivation and by urban sprawl. This vegetation unit has a high grazing capacity and this leads to overutilisation and degradation, and subsequent invasion of *Acacia karroo* into adjacent dry grassland. Due to the great habitat and floristic diversity and for aesthetical reasons, the landscape deserves to be conserved.

References Louw (1951), Morris (1973, 1976), Bredenkamp & Bezuidenhout (1990), Bezuidenhout (1993), Bezuidenhout et al. (1994c, d).

Gh 14 Western Highveld Sandy Grassland

VT 50 Dry *Cymbopogon–Themeda* Veld (61%) (Acocks 1953). LR 37 Dry Sandy Highveld Grassland (74%) (Low & Rebelo 1996).

Distribution North-West Province: From Mafikeng to Schweizer-Reneke in the south and from Broedersput and Kameel in the west to Lichtenburg and Ottosdal in the east. Altitude 1 280–1 520 m, main area at 1 340–1 380 m.

Vegetation & Landscape Features Flat to gently undulating plains with short, dry grassland, with some woody species occurring in bush clumps.

Geology & Soils Basaltic lavas of the Klipriviersberg Group and andesitic lavas of the Allanridge Formation (both Ventersdorp Supergroup) covered by aeolian sand (western part of the area) or calcrete, with the eutrophic plinthic soils, which are mainly yellow apedals (Avalon and Pinedene) and rarely red apedals (Hutton) or Clovelly in bottomlands. Bd land type dominant.

Climate Warm-temperate, summer-rainfall region, with overall MAP of 520 mm. Summer temperatures are high. Severe frequent frost occurs in winter. See also climate diagram for Gh 14 Western Highveld Sandy Grassland (Figure 8.23).

Important Taxa Graminoids: *Anthephora pubescens* (d), *Aristida congesta* (d), *A. diffusa* (d), *Cymbopogon pospischilii* (d), *Cynodon dactylon* (d), *Eragrostis lehmanniana* (d), *E. trichophora* (d), *Panicum coloratum* (d), *Pogonarthria squarrosa* (d), *Setaria sphacelata* (d), *Sporobolus africanus* (d), *Themeda triandra* (d), *Aristida adscensionis*, *A. canescens*, *A. stipitata* subsp. *graciliflora*, *Brachiaria serrata*, *Digitaria argyrograpta*, *D. eriantha*, *Diheteropogon amplectens*, *Elionurus muticus*, *Eragrostis chloromelas*, *E. curvula*, *E. gummiflua*, *E. racemosa*, *Eustachys paspaloides*, *Heteropogon contortus*, *Melinis nerviglumis*, *Sporobolus discosporus*, *S. fimbriatus*, *Trichoneura grandiglumis*, *Triraphis andropogonoides*. Herbs: *Gazania krebsiana* subsp. *krebsiana* (d), *Stachys spathulata* (d), *Barleria macrostegia*, *Berkheya onopordifolia* var. *onopordifolia*, *Chamaecrista mimosoides*, *Chamaesyce inaequilatera*, *Dicoma anomala*, *D. macrocephala*, *Helichrysum callicomum*, *Hermannia depressa*, *H.*

E.M. Daemane

Figure 8.34 Gh 13 Klerksdorp Thornveld: *Acacia karroo*-dominated thickets in a grassland matrix of the eastern highveld near Klerksdorp (North-West Province).

tomentosa, *Kyphocarpa angustifolia*, *Lippia scaberrima*, *Monsonia burkeana*, *Nolletia ciliaris*, *Osteospermum muricatum* subsp. *longiradiatum*, *Pollichia campestris*, *Rhynchosia adenodes*, *Sebaea grandis*, *Trichodesma angustifolium* subsp. *angustifolium*, *Vernonia oligocephala*. Geophytic Herb: *Boophone disticha*. Low Shrubs: *Anthospermum rigidum* subsp. *pumilum* (d), *Aptosimum elongatum*, *Felicia muricata*, *Gnidia capitata*, *Helichrysum paronychioides*, *Indigofera comosa*, *Leucas capensis*, *Polygala hottentotta*, *Sida dregei*, *Solanum panduriforme, Stoebe plumosa*. Tall Shrubs: *Acacia hebeclada*, *Diospyros lycioides* subsp. *lycioides*.

D.B. Hoare

Figure 8.35 Gh 15 Carletonville Dolomite Grassland: Grassy rocky outcrop at Vlakplaats, west of Valhalla near Centurion (Gauteng) with prominent grasses such as *Loudetia simplex*, *Hyparrhenia hirta*, *Brachiaria serrata* and *Heteropogon contortus* and scattered shrubs including *Euclea undulata*, *Rhus magalismontanum*, *Zanthoxylum capense* and *Diospyros lycioides*.

Conservation Endangered. Target 24%. Only a very small portion statutorily conserved (Barberspan Nature Reserve). More than 60% has been ploughed. Nonarable parts are on shallow aeolian soils which become easily overutilised through grazing. Erosion is very low. About 95% of this land is suitable for cultivation, but the low rainfall makes it a high-risk area for agriculture. Therefore the natural vegetation is often restricted to nonarable bush clumps, shallow soils, aeolian sands and pans.

Remarks Many endorheic pans (AZi 10 Highveld Salt Pans; see the chapter on Inland Azonal Vegetation in this book) are embedded within this grassland, especially in the north.

References Morris (1973, 1976), Bezuidenhout (1993), Bezuidenhout et al. (1993, 1994c).

Gh 15 Carletonville Dolomite Grassland

VT 61 Bankenveld (65%) (Acocks 1953). LR 34 Rocky Highveld Grassland (88%) (Low & Rebelo 1996).

Distribution North-West (mainly) and Gauteng and marginally into the Free State Province: In the region of Potchefstroom, Ventersdorp and Carletonville, extending westwards to the vicinity of Ottoshoop, but also occurring as far east as Centurion and Bapsfontein in Gauteng Province. Altitude 1 360–1 620 m, but largely 1 500–1 560 m.

Vegetation & Landscape Features Slightly undulating plains dissected by prominent rocky chert ridges. Species-rich grasslands forming a complex mosaic pattern dominated by many species.

Geology & Soils Dolomite and chert of the Malmani Subgroup (Transvaal Supergroup) supporting mostly shallow Mispah and Glenrosa soil forms typical of the Fa land type, dominating the landscapes of this unit. Deeper red to yellow apedal soils (Hutton and Clovelly forms) occur sporadically, representing the Ab land type.

Climate Warm-temperate, summer-rainfall region, with overall MAP of 593 mm. Summer temperatures high. Severe frequent frost occurs in winter. See also climate diagram for Gh 15 Carletonville Dolomite Grassland (Figure 8.23).

Important Taxa Graminoids: *Aristida congesta* (d), *Brachiaria serrata* (d), *Cynodon dactylon* (d), *Digitaria tricholaenoides* (d), *Diheteropogon amplectens* (d), *Eragrostis chloromelas* (d), *E. racemosa* (d), *Heteropogon contortus* (d), *Loudetia simplex* (d), *Schizachyrium sanguineum* (d), *Setaria sphacelata* (d), *Themeda triandra* (d), *Alloteropsis semialata* subsp. *eckloniana*, *Andropogon schirensis*, *Aristida canescens*, *A. diffusa*, *Bewsia biflora*, *Bulbostylis burchellii*, *Cymbopogon caesius*, *C. pospischilii*, *Elionurus muticus*, *Eragrostis curvula*, *E. gummiflua*, *E. plana*, *Eustachys paspaloides*, *Hyparrhenia hirta*, *Melinis nerviglumis*, *M. repens* subsp. *repens*, *Monocymbium ceresiiforme*, *Panicum coloratum*, *Pogonarthria squarrosa*, *Trichoneura grandiglumis*, *Triraphis andropogonoides*, *Tristachya leucothrix*, *T. rehmannii*. Herbs: *Acalypha angustata*, *Barleria macrostegia*, *Chamaecrista mimosoides*, *Chamaesyce inaequilatera*, *Crabbea angustifolia*, *Dianthus mooiensis*, *Dicoma anomala*, *Helichrysum caespititium*, *H. miconiifolium*, *H. nudifolium* var. *nudifolium*, *Ipomoea ommaneyi*, *Justicia anagalloides*, *Kohautia amatymbica*, *Kyphocarpa angustifolia*, *Ophrestia oblongifolia*, *Pollichia campestris*, *Senecio coronatus*, *Vernonia oligocephala*. Geophytic Herbs: *Boophone disticha*, *Habenaria mossii*. Low Shrubs: *Anthospermum rigidum* subsp. *pumilum*, *Indigofera comosa*, *Pygmaeothamnus zeyheri* var. *rogersii*, *Rhus magalismontana*, *Tylosema esculentum*, *Ziziphus zeyheriana*. Geoxylic Suffrutices: *Elephantorrhiza elephantina*, *Parinari capensis* subsp. *capensis*.

Endemic Taxon Succulent Shrub: *Delosperma davyi*.

Conservation Vulnerable. Target 24%. Small extent conserved in statutory (Sterkfontein Caves—part of the Cradle of Humankind World Heritage Site, Oog Van Malmanie, Abe Bailey, Boskop Dam, Schoonspruit, Krugersdorp, Olifantsvlei, Groenkloof) and in at least six private conservation areas. Almost a quarter already transformed for cultivation, by urban sprawl or by mining activity as well as the building of the Boskop and Klerkskraal Dams. Erosion very low (84%) and low (15%).

References Louw (1951), Morris (1973, 1976), Coetzee (1974), Coetzee & Werger (1975), Van Wyk (1983), Van Wyk & Bredenkamp (1986), Bezuidenhout & Bredenkamp (1990), Scogings & Theron (1990), Bezuidenhout et al. (1994b, c, f), Bredenkamp et al. (1994), Grobler (2000), Hartmann (2001), Siebert & Siebert (2005), Grobler et al. (2006).

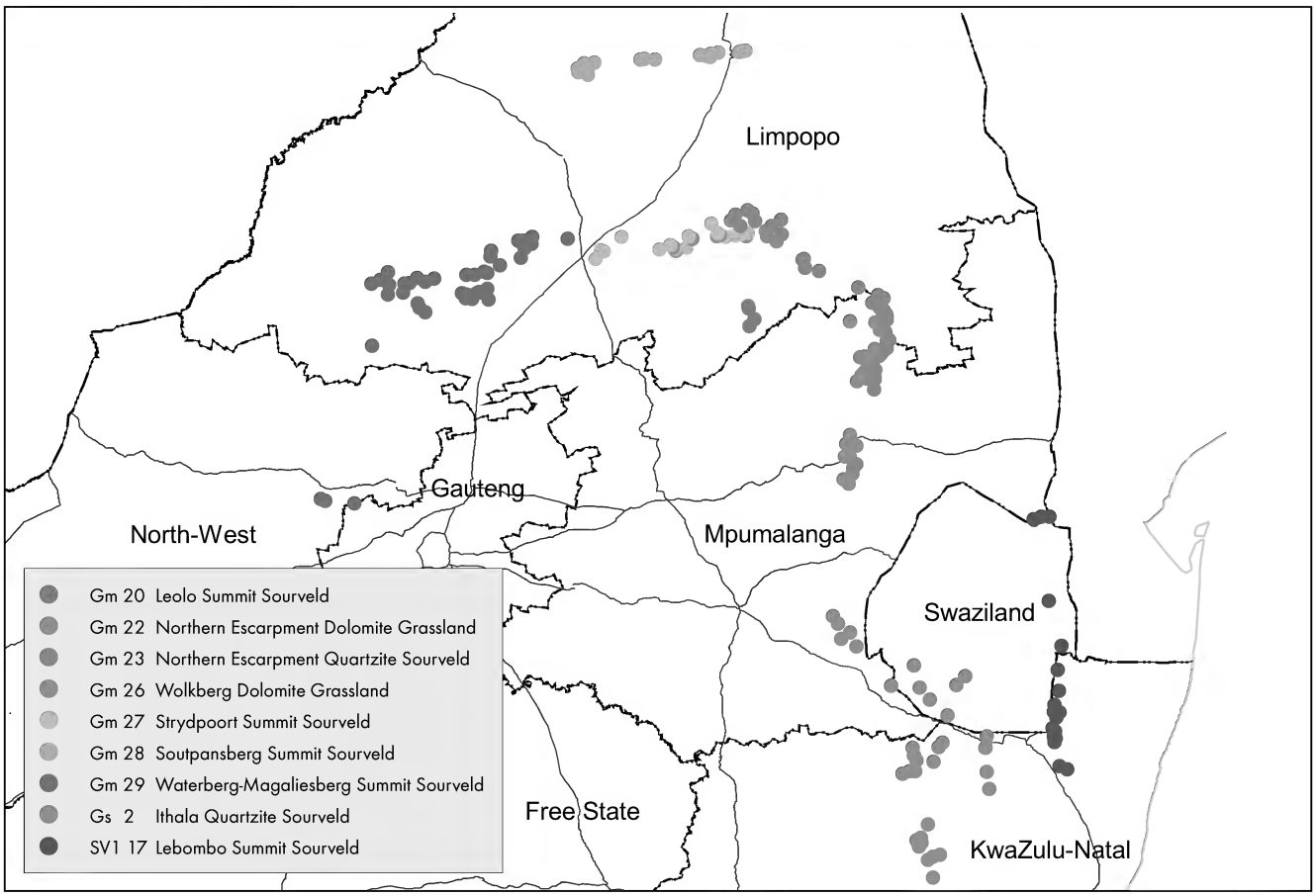


Figure 8.37 Position of the 'sourveld' grassland units, usually straddling the border of the Grassland and Savanna Biomes in the northern and northeastern regions of South Africa and Swaziland.

Mesic Highveld Grassland

Mesic Highveld Grassland is found mainly in the eastern, precipitation-rich regions of the Highveld, extending as far as the Northern Escarpment (Figure 8.36). These are considered to be 'sour' grasslands, and are dominated primarily by andropogonoid grasses. The different grassland units are distinguished on the basis of geology and other substrate properties, as well as elevation, topography and rainfall.

Shrublands are found on outcrops of rock within Mesic Highveld Grassland (Figure 8.24), where the surface topography creates habitats in which woody vegetation is favoured above grasses. This may include protection from fire and grazing or conditions under which woody plants can access subterranean water supplies. Generally, the higher the surface rock cover, the higher the cover of woody vegetation relative to herbaceous vegetation. The rocky outcrops are mostly of volcanic origin, e.g. dolerite, and are more resistant to weathering in addition to having more nutrient-rich soils.

Summit grasslands are a unique subgroup of the Mesic Highveld Grassland. They are sourvelds found on the summit of the mountain ranges that occur embedded within the Savanna Biome north of the 25° S latitude (Figure 8.37). There is a physical separation between these grasslands and other grassland vegetation in the core biome area of the central Highveld due to the presence of extensive areas of savanna woodlands in between. They are therefore extrazonal grassland vegetation units. The climate in these areas is generally warm and moist and it is the lack of well-developed soils as well as the unique geological influences on these mountains that determines the presence of grassland vegetation instead of savanna in these areas, although the local increased elevation also simulates conditions found in the core Grassland Biome. Due to the substrate factors, the grasslands in these areas often have unique floristic elements and high levels of endemism.

Gm 1 Zastron Moist Grassland

VT 48 *Cymbopogon–Themeda* Veld (sandy) (77%) (Acocks 1953). LR 40 Moist Cold Highveld Grassland (80%) (Low & Rebelo 1996).

Distribution Eastern Cape and Free State Provinces and Lesotho: Surrounds of Zastron, extends just short of Van Stadensrus (north) to Mohales Hoek (northeast) and Rouxville (west). A narrow corridor extends south towards Jamestown and Dordrecht. Altitude 1 400–1 720 m.

Vegetation & Landscape Features Undulating plains, broken in places due to sandstone outcrops forming extensive terraces. These plains bear a mosaic of moist open sour grassland with affinity to Gm 4 Eastern Free State Sandy Grassland, on elevated areas above sandstone outcrops and Gm 3 Eastern Free State Clay Grassland in low-lying eroded areas as well as mudstone outcrops.

Geology & Soils Relatively deep sandy layer over the sandstone layers of the Tarkastad Subgroup (Molteno and Elliot Formations) of the Beaufort Group (Karoo Supergroup). Typical soil forms present on these sandstone terraces are Clovelly and Avalon. Clayey soils, which were formed by weathering and leaching processes, are concentrated in low-lying drainage lines,

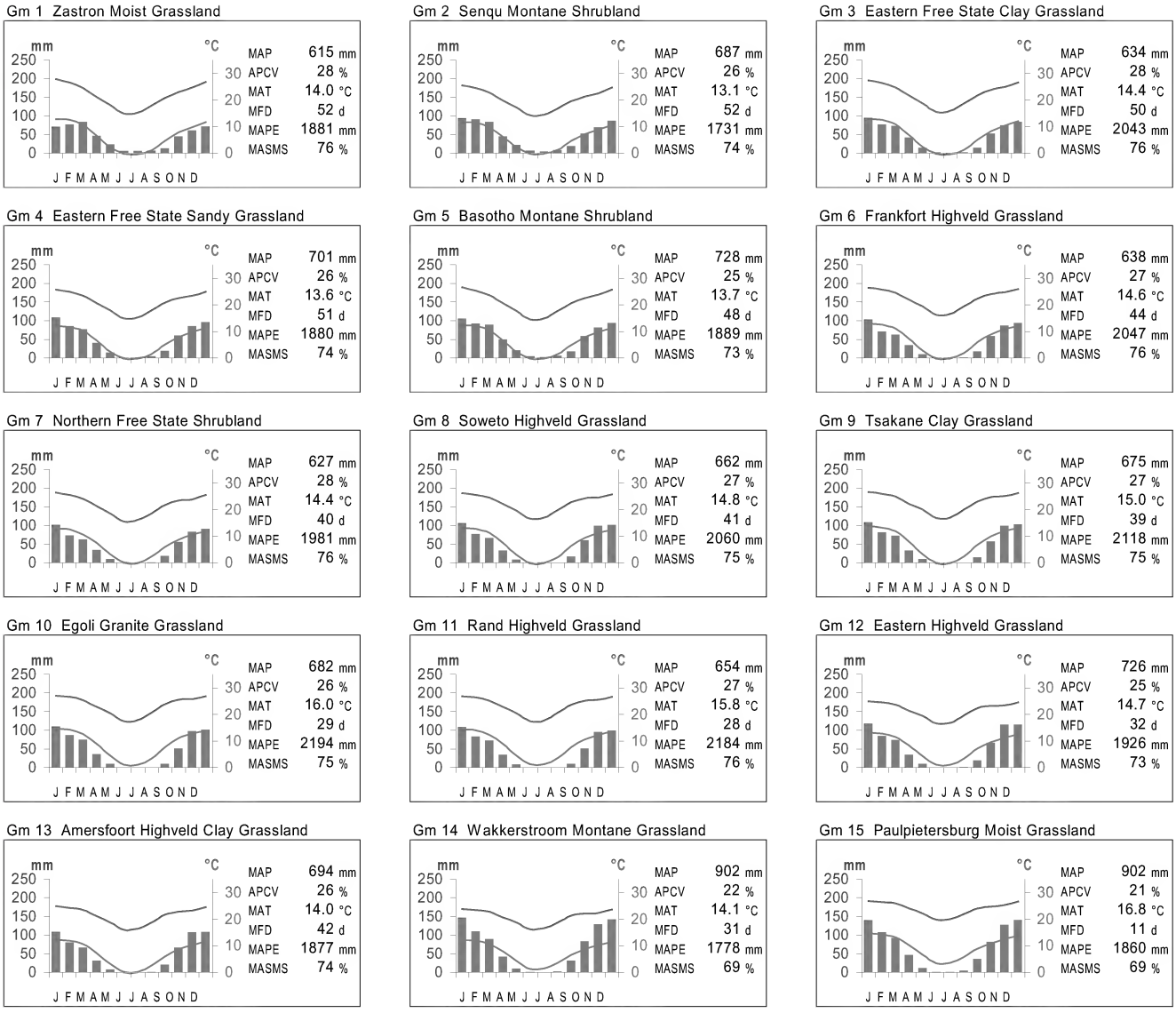
L. Mucina

Figure 8.38 Gm 1 Zastron Moist Grassland: Grasslands at the foot of Aasvoëlberg (2 208 m) near Zastron (Free State), with open shrublands of Gh 4 Besemkaree Koppies Shrubland on the slopes.

valley bottoms and depressions. Db land type dominates, with typical soil forms such as Estcourt and Oakleaf forms present. Fb and Ca land types of minor importance.

Climate Summer rainfall which peaks in March. MAP 615 mm. MAT of 14°C indicates cool-temperate climate. The inland position of the unit results in high thermic continentality: summers are very hot, while winter can be bitterly cold. Frost is a common phenomenon. See also climate diagram for Gm 1 Zastron Moist Grassland (Figure 8.36).

Important Taxa Graminoids: *Aristida congesta* (d), *Cymbopogon pospischilii* (d), *Digitaria argyrograpta* (d), *Eragrostis chloromelas* (d), *Microchloa caffra* (d), *Setaria sphacelata* (d), *Themeda triandra* (d), *Andropogon appendiculatus*, *Brachiaria serrata*, *Cynodon incompletus*, *Cyperus obtusiflorus* var. *obtusiflorus*, *Elionurus muticus*, *Eragrostis capensis*, *E. curvula*, *E. lehmanniana*, *E. plana*, *E.*



racemosa, *Festuca scabra*, *Harpochloa falx*, *Heteropogon contortus*, *Panicum gilvum*, *Sporobolus africanus*, *Tetrachne dregei*, *Trichoneura grandiglumis*, *Triraphis andropogonoides*. Herbs: *Berkheya onopordifolia* var. *onopordifolia*, *Dianthus thunbergii*, *Gazania krebsiana* subsp. *krebsiana*, *Helichrysum rugulosum*, *Hermannia depressa*, *Limeum argute-carinatum*, *Nolletia ciliaris*, *Salvia stenophylla*, *Senecio erubescens* var. *crepidifolius*, *Trichogyne paronychioides*, *Wahlenbergia denticulata*. Geophytic Herb: *Moraea pallida*. Low Shrubs: *Helichrysum dregeanum* (d), *Anthospermum rigidum* subsp. *pumilum*, *Chrysocoma ciliata*, *Felicia muricata*, *Helichrysum asperum* var. *albidulum*, *H. niveum*, *Selago saxatilis*, *Senecio burchellii*.

Endemic Taxon Geophytic Herb: *Dierama jucundum*.

Conservation Vulnerable. Target 24%. None conserved in statutory conservation areas and only very small portion protected in private Vulture Conservation Area. Almost a third already transformed by cultivation or by urban sprawl. Erosion high (45%), moderate (26%), very high (19%) and low (10%).

Remarks This unit is a mosaic of sweet and sour grassland communities interspersed with rock outcrops capped with dolerite and supporting Gh 4 Besemkaree Koppies Shrubland, or capped by sandstone and supporting Gm 5 Basotho Montane Shrubland. The slopes of the higher mountains such as Aasvoëlberg, Elandsberg, Vegkop and the like in the Zastron District support Gm 5 Basotho Montane Shrubland containing some afromontane elements. This is the only area in the Free State where extensive stands of *Aloe ferox* are found. It is furthermore, together with the Gm 2 Senqu Montane Shrubland, the highest above sea level and furthest inland localities in the distribution range of *A. ferox*. Karroid shrublands are present in areas (such as Sterkspruit) that have suffered heavy overgrazing.

References Acocks (1953, 1988), Werger (1980), Du Preez & Bredenkamp (1991), Malan (1998), Malan et al. (1999).

Gm 2 Senqu Montane Shrubland

VT 48 *Cymbopogon–Themeda* Veld (sandy) (48%), VT 58 *Themeda–Festuca* Alpine Veld (47%) (Acocks 1953). LR 45 Afro Mountain Grassland (50%) (Low & Rebelo 1996).

Distribution Lesotho as well as in Eastern Cape and Free State Provinces (only marginal patches): Mainly in the lower Senqu Valley, particularly in the Moyeni (Quthing)–Mount Moorosi regions, strongly attenuating upstream northwards in the direction of Thaba-Tseka. Extends into South Africa mainly south of the Orange River (continuation of the Senqu River from Lesotho) in the Herschel District. This shrubland unit covers the

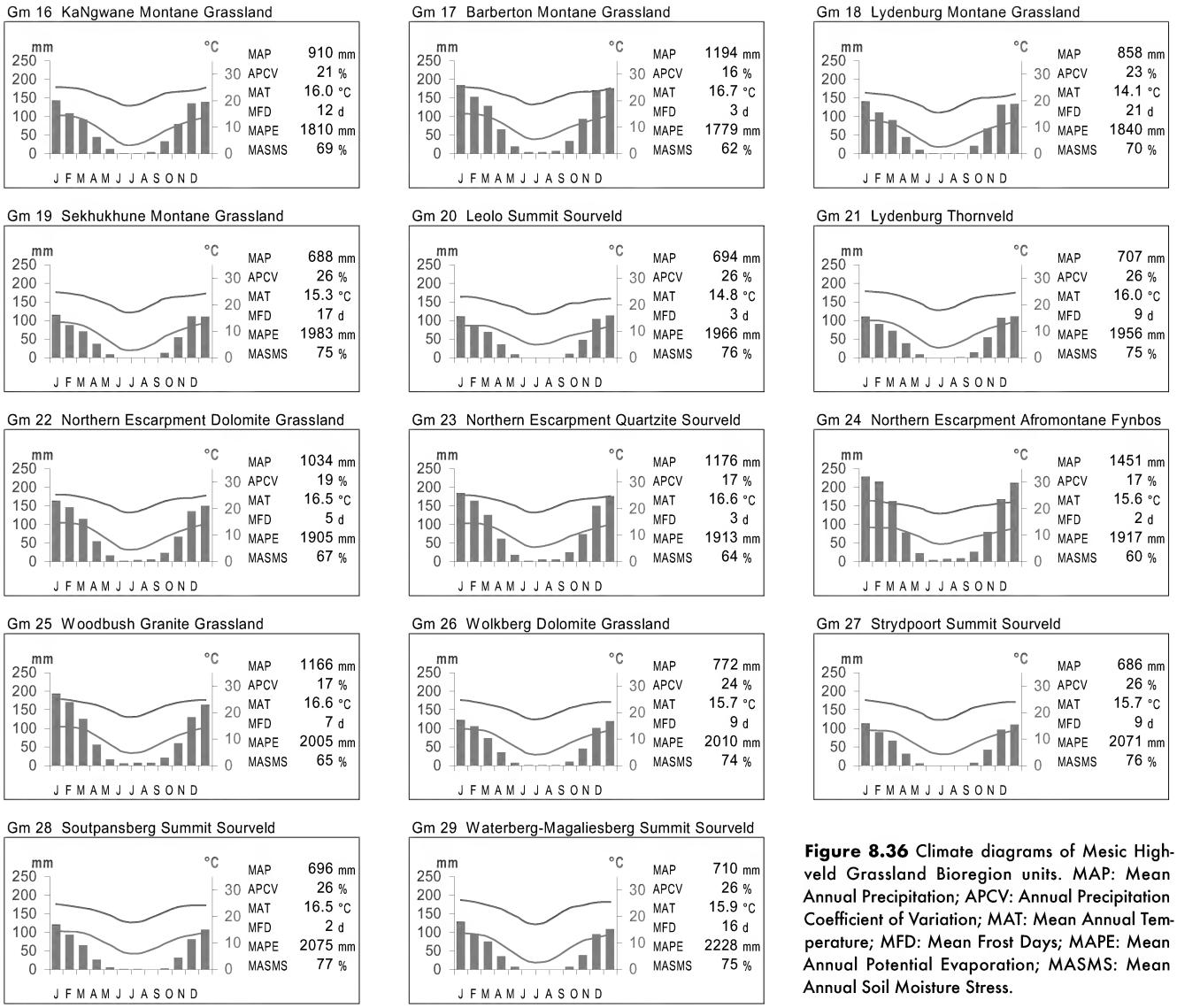


Figure 8.36 Climate diagrams of Mesic Highveld Grassland Bioregion units. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days; MAPE: Mean Annual Potential Evaporation; MASMS: Mean Annual Soil Moisture Stress.

M.C. Rutherford

Figure 8.39 Gm 2 Senqu Montane Shrubland: Steep northern slopes of Thaba Moorosi dominated by *Aloe ferox* and shrubs including *Rhus erosa* and *Olea europaea* subsp. *africana* in the lower valley of the Quthing River shortly before it joins the Senqu River, north of the town of Mount Moorosi, Lesotho.

valley slopes of the Senqu River as well as its numerous tributaries. Altitude 1 600–1 900 m, with outliers found as low as 1 440 m and reaching 1 960 m in places.

Vegetation & Landscape Features Restricted to steep, boulder-strewn slopes of valleys and deep gullies, supporting open-canopy montane shrubland. The shrub species diversity decreases towards low-lying, southwestern areas. The vegetation is dominated by evergreen shrubs, namely *Rhus erosa*, *Olea europaea* and *Diospyros austro-africana*. In a few sheltered inaccessible areas the shrubland turns into thicket with *Kiggelaria africana*, *Leucosidea sericea* and *Rhamnus prinoides*.

Geology & Soils Karoo Supergroup sedimentary rocks of the Clarens, Elliot and Molteno Formations as the Senqu River cuts through the landscape in the low-lying southwestern regions. Intrusive Drakensberg Group (Jurassic) basalts at high altitudes at the interface with the Gd 8 Lesotho Highland Basalt Grassland. Dominant land type Fa, followed by the Ea. The most common soil forms that dominate these land types are Mispah and Glenrosa.

Climate Summer rainfall, with overall MAP of 687 mm. Much of the rainfall is convectional. Cool-temperate thermic pattern (MAT around 13°C), with 52 days of frost incidence. See also climate diagram for Gm 2 Senqu Montane Shrubland (Figure 8.36).

Important Taxa Succulent Tree: *Aloe ferox* (d). Small Trees: *Acacia karroo*, *Celtis africana*, *Cussonia paniculata*, *Kiggelaria africana*, *Pittosporum viridiflorum*. Tall Shrubs: *Diospyros austro-africana* var. *rubriflora* (d), *D. lycioides* subsp. *lycioides* (d), *Euclea coriacea* (d), *Rhamnus prinoides* (d), *Rhus divaricata* (d), *R. erosa* (d), *Buddleja loricata*, *B. salviifolia*, *Clutia pulchella*, *Euclea crispa* subsp. *crispa*, *Grewia occidentalis*, *Gymnosporia heterophylla*, *Heteromorpha arborescens* var. *abyssinica*, *Myrsine africana*, *Olea europaea* subsp. *africana*, *Passerina montana*, *Polygala virgata* var. *decora*, *Rhus burchellii*, *R. dentata*, *R. pyroides*, *Tarchonanthus minor*. Low Shrubs: *Artemisia afra* (d), *Chrysocoma ciliata* (d), *Felicia filifolia* (d), *Helichrysum melanacme* (d), *Agathosma ovata*, *Anthospermum rigidum* subsp. *pumilum*, *Clutia hirsuta*, *Eriocephalus tenuifolius*, *Euryops oligoglossus* subsp. *oligoglossus*, *Gomphocarpus fruticosus* subsp. *fruticosus*, *Gomphostigma virgatum*, *Helichrysum odoratissimum*, *H. zeyheri*, *Heliophila carnosa*, *Indigofera nigromontana*, *Lantana rugosa*, *Melolobium candicans*, *Morella serrata*, *Muraltia saxicola*, *Nenax microphylla*, *Polygala uncinata*, *Printzia auriculata*, *Rhus dregeana*, *Rubus ludwigii*, *Senecio pterophorus*, *Solanum tomentosum*, *Stachys rugosa*. Succulent Shrubs: *Aloe broomii*, *Chasmatophyllum musculinum*, *C. verdoorniae*, *Delosperma ashtonii*, *D. concavum*, *D. congestum*, *D. hirtum*, *D. obtusum*, *Euphorbia clavarioides* var. *clavarioides*, *E. pulvinata*. Semiparasitic Shrub: *Osyris lanceolata*. Semiparasitic Epiphytic Shrub: *Viscum hoolei*. Graminoids: *Eragrostis curvula* (d), *Hyparrhenia hirta* (d), *Agrostis subulifolia*, *Andropogon appendiculatus*, *Aristida bipartita*, *A. congesta*, *A. diffusa*, *A. junciformis* subsp. *galpinii*, *Brachiaria nigropedata*, *Cymbopogon nardus*, *C. pospischilii*, *Elionurus muticus*, *Eragrostis capensis*, *E. chloromelas*, *E. pallens*, *E. plana*, *E. planiculmis*, *E. racemosa*, *E. trichophora*, *Harpochloa falx*, *Helictotrichon longifolium*, *Heteropogon contortus*, *Hordeum capense*, *Hyparrhenia anamesa*, *Koeleria capensis*, *Melica decumbens*, *M. racemosa*, *Melinis nerviglumis*, *Merxmuellera disticha*, *Microchloa caffra*, *Pennisetum macrourum*, *P. sphacelatum*, *Pentaschistis setifolia*, *Setaria sphacelata*, *Sporobolus africanus*, *S. centrifugus*, *S. fimbriatus*, *Stipagrostis uniplumis* var. *neesii*, *Streblochaete longiarista*, *Tetrachne dregei*, *Themeda triandra*, *Trachypogon spicatus*, *Tragus racemosus*, *Tristachya leucothrix*. Woody Climber: *Clematis brachiata*. Herbs: *Aster bakerianus*, *Berkheya setifera*, *Chamaesyce inaequilatera*, *Commelina africana*, *Convolvulus thunbergii*, *Dicoma anomala*, *Erucastrum strigosum*, *Geigeria filifolia*, *Gerbera piloselloides*, *Haplocarpha scaposa*, *Helichrysum caespititium*, *H. chionosphaerum*, *Hermannia coccocarpa*, *H. depressa*, *H. gerrardii*, *Lobelia flaccida*, *Monsonia angustifolia*, *Nemesia rupicola*, *Rhynchosia pentheri*, *Salvia stenophylla*, *Sebaea natalensis*, *Selago galpinii*, *Senecio asperulus*, *S. bupleuroides*, *S. subcoriaceus*, *Tribulus terrestris*, *Ursinia saxatilis*. Herbaceous Climbers: *Dolichos linearis*, *Kedrostis nana*. Geophytic Herbs: *Albuca setosa*, *Androcymbium burkei*, *Asclepias gibba*, *A. multicaulis*, *Bulbine abyssinica*, *B. capitata*, *B. frutescens*, *Cheilanthes eckloniana*, *C. viridis*, *Ledebouria cooperi*, *Moraea pallida*, *Pellaea calomelanos*, *Raphionacme hirsuta*, *Schizoglossum bidens* subsp. *bidens*, *Zantedeschia albomaculata* subsp. *albomaculata*. Succulent Herbs: *Aloe maculata*, *A. pratensis*, *Crassula capitella*, *C. lanceolata* subsp. *lanceolata*, *C. muscosa*, *C. nudicaulis*. Semiparasitic Herbs: *Alectra capensis*, *Thesium costatum* var. *juniperinum*.

Biogeographically Important Taxa ([D]Drakensberg endemic, [Dg]Drakensberg endemic extending to Griqualand East) Low Shrubs: *Euryops tysonii*[D], *Relhania acerosa*[Dg], *R. dieterlenii*[D]. Herbs: *Diascia integerrima*[D], *Helichrysum elegantissimum*[D].

Conservation Least threatened. Target 28%. None conserved in statutory conservation areas. Some 14% already transformed for cultivation. Wood collection is putting this vegetation under severe pressure. Accessible areas have been severely degraded and the shrubland has been reduced. Erosion (ranging across large scales of intensity), caused by degradation of the shrubland vegetation, has resulted in the formation of dongas that cut back into the valleys, destroying the remaining riparian

vegetation in places. Much of the upper reaches of this vegetation unit will disappear should the planned further phases (II, III and IV) of the Lesotho Highlands Water Project be implemented and result in the construction of the Mashai, Tsoelike and Ntoahae Dams.

Remarks This unit is possibly one of the driest of the moist grassland units, some areas with MAP below 600 mm and possibly in places even less than 550 mm (Anonymous 2000). Upstream along the Senqu River, at the Koma-Koma Causeway, the area appears almost hyper-arid, although it is difficult to assess the contribution of the high impact of human and animal pressures. This unit is also recognised by Anonymous (2000) as one of four 'ecological zones' of Lesotho.

References Boucher & Tlale (1999a, b), Anonymous (2000).

Gm 3 Eastern Free State Clay Grassland

VT 48 *Cymbopogon–Themeda* Veld (sandy) (83%) (Acocks 1953). LR 39 Moist Cool Highveld Grassland (73%) (Low & Rebelo 1996).

Distribution Free State Province and marginally in Lesotho: Low-lying areas of the eastern regions of the province, covering the vicinities of Wepener (south), Petrus Steyn (north), Excelsior and east of Winburg (west) and Warden (east) and a thin extension between Maseru and Fouriesburg. Altitude 1 380–1 740 m.

Vegetation & Landscape Features Flat to gently rolling land surfaces covered with grassland dominated by *Eragrostis curvula*, *Themeda triandra*, *Cymbopogon pospischilii*, *Eragrostis plana*, *Setaria sphacelata*, *Elionurus muticus* and *Aristida congesta*. Overgrazing in certain areas and selective grazing of the grassland create a patchy appearance, with dominant and diagnostic species associated with small to large patches of a few hectares in diameter. A wide range of grazing regimes on the macro-scale and within grazing units in the area on the micro-scale, create this fragmentation (Fuls 1993).

Geology & Soils Mudstones and sandstones of the Adelaide Formation (Beaufort Group) underlie this flat to slightly undulating terrain in the north, while the Tarkastad Formation (Beaufort Group) dominates the geology in the south. Dolerite dykes and sills as well as sandstone outcrops, resistant to weathering, form isolated hills and ridges (Gm 5 Basotho Montane Shrubland) that create a broken landscape, especially in the southern parts of the unit. Sepane, Arcadia, Estcourt and Rensburg forms dominate the moist bottomlands while the Glenrosa, Bonheim, Avalon, Clovelly and Mayo forms dominate the outcrops and slightly elevated areas. Major land types Ca and Bd.

Climate Summer-rainfall region, with MAP around 630 mm. Much of the precipitation falls in form of thunderstorms between November and March. One of the coldest regions of the Highveld. Frost is very frequent in winter. See also climate diagram for Gm 3 Eastern Free State Clay Grassland (Figure 8.36).

Important Taxa Graminoids: *Andropogon appendiculatus* (d), *Aristida congesta* (d), *Brachiaria serrata* (d), *Cymbopogon pospischilii* (d), *Cynodon dactylon* (d), *Elionurus muticus* (d), *Eragrostis chloromelas* (d), *E. plana* (d), *Harpochloa falx* (d), *Heteropogon contortus* (d), *Microchloa caffra* (d), *Miscanthus capensis* (d), *Panicum gilvum* (d), *Pennisetum sphacelatum* (d), *Setaria sphacelata* (d), *Themeda triandra* (d), *Tristachya leucothrix* (d), *Aristida junciformis* subsp. *galpinii*, *Eragrostis capensis*, *E. gummiflua*, *E. racemosa*, *Panicum stapfianum*, *Setaria nigrirostris*, *Trichoneura grandiglumis*. Herbs: *Vernonia oligocephala* (d), *Ajuga ophrydis*, *Berkheya onopordifolia* var. *onopordifolia*, *Chamaesyce inaequilatera*, *Cineraria lyratiformis*, *Crabbea acaulis*, *Geigeria aspera* var. *aspera*, *Haplocarpha scaposa*, *Helichrysum rugulosum*, *Hermannia depressa*, *Hibiscus microcarpus*, *Monsonia burkeana*, *Nolletia ciliaris*, *Selago densiflora*, *Sonchus dregeanus*, *S. nanus*, *Tolpis capensis*. Geophytic Herbs: *Boophone disticha*, *Crinum bulbispermum*, *Kniphofia ritualis*, *Ledebouria macowanii*. Herbaceous Climber: *Rhynchosia totta*. Low Shrubs: *Helichrysum dregeanum* (d), *Anthospermum rigidum* subsp. *pumilum*, *Felicia muricata*, *Pentzia globosa*, *Stoebe plumosa*. Succulent Shrub: *Euphorbia clavarioides* var. *clavarioides*.

Conservation Endangered. Target 24%. Only a small portion statutorily conserved (Willem Pretorius Nature Reserve). More than half already transformed by cultivation or building of dams (Allemanskraal, Armenia, Egmont, Loch Lomond, Lovedale, Mushroom Valley and Newberry Dams). Erosion very low (34%), low (30%) and moderate (26%).

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Figure 8.40 Gm 3 Eastern Free State Clay Grassland: Tall grasslands in the broad valley of the Klerkspruit near Bothasberg south of Kestell (eastern Free State). The peaks of the Rooiberge (Golden Gate Highlands National Park) are visible in the background.

Remarks Several clusters of AZf 3 Eastern Temperate Freshwater Wetlands (playas) occur in an area between Lindley, Bethlehem, Warden and Petrus Steyn. These playas are probably the remains of palaeodrainage lines (Seaman 1987).

References Scheepers (1975), Seaman (1987), Du Preez (1991), Fuls (1993).

Gm 4 Eastern Free State Sandy Grassland

VT 56 Highland Sourveld to *Cymbopogon–Themeda* Veld Transition (Eastern Free State Highveld) (42%), VT 48 *Cymbopogon–Themeda* Veld (sandy) (31%) (Acocks 1953). LR 40 Moist Cold Highveld Grassland (60%) (Low & Rebelo 1996).

Distribution Free State Province, Lesotho and marginally into KwaZulu-Natal Province: Ladybrand (west) to the base of foothills of the Drakensberg (Maloti) and the Escarpment in the vicin-

ity of Harrismith (east) and Mafeteng (south). The towns of Marquard, Paul Roux, Bethlehem, Memel and Vrede bound this unit on its northern border. Altitude 1 520–1 800 m, but reaching 2 020 m in places.

Vegetation & Landscape Features Flat to slightly undulating and undulating terrain with streams and rivers that drain the foothills of the Drakensberg. Closed grassland dominated by *Eragrostis curvula*, *Tristachya leucothrix* and *Themeda triandra*. Other dominant grasses include *E. capensis*, *E. racemosa*, *Cymbopogon pospischilii*, *Elionurus muticus*, *Eragrostis plana* and *Aristida junciformis*. Numerous herb species (especially Asteraceae: species of *Helichrysum*, *Vernonia*, *Berkheya*) increase alpha diversity considerably. Embedded within many hills and small mountains carrying Gm 5 Basotho Montane Shrubland. Due to wide range of grazing and fire regimes, the grassland has a patchy appearance.

Geology & Soils Mudstones, sandstones and shale of the Beaufort Group (Tarkastad Formation in the south and Adelaide Formation in the north). Glenrosa, Bonheim, Avalon and Mayo soil forms dominate the outcrops and slightly elevated areas while Sepane, Arcadia and Rensburg soil forms are typical for moist bottomlands. Major land types Bb, Bd and Ca.

Climate Summer-rainfall region, with MAP around 700 mm. Much of the precipitation falls in form of thunderstorms between November and March. Great differences between the average temperatures in winter and summer as well as very frequent occurrence of frost confirm a continental climate. See also description of climate for Gm 3 Eastern Free State Clay Grassland and climate diagram for Gm 4 Eastern Free State Sandy Grassland (Figure 8.36).

Important Taxa Graminoids: *Aristida junciformis* subsp. *galpinii* (d), *Cymbopogon pospischilii* (d), *Digitaria monodactyla* (d), *D. tricholaenoides* (d), *Elionurus muticus* (d), *Eragrostis chloromelas* (d), *E. curvula* (d), *E. plana* (d), *E. racemosa* (d), *Harpochloa falx* (d), *Heteropogon contortus* (d), *Hyparrhenia hirta* (d), *Microchloa caffra* (d), *Monocymbium ceresiiforme* (d), *Setaria sphacelata* (d), *Themeda triandra* (d), *Tristachya leucothrix* (d), *Andropogon appendiculatus*, *A. schirensis*, *Aristida congesta*, *A. diffusa*, *Brachiaria serrata*, *Cymbopogon caesius*, *Cynodon dactylon*, *Cyperus obtusiflorus* var. *flavissimus*, *C. obtusiflorus* var. *obtusiflorus*, *Diheteropogon amplectens*, *Ehrharta capensis*, *Eragrostis capensis*, *Helictotrichon natalense*, *H. turgidulum*, *Koeleria capensis*, *Panicum gilvum*, *Setaria nigrirostris*, *Trachypogon spicatus*, *Trichoneura grandiglumis*. Herbs: *Barleria monticola* (d), *Berkheya onopordifolia* var. *onopordifolia* (d), *B. speciosa* (d), *Dicoma anomala* (d), *Helichrysum psilolepis* (d), *Acalypha angustata*, *A. peduncularis*, *Ajuga ophrydis*, *Anthospermum herbaceum*, *Berkheya pinnatifida*, *B. setifera*, *Crabbea acaulis*, *Cycnium racemosum*, *Dianthus basuticus*, *Haplocarpha scaposa*, *Hebenstretia dentata*, *H. dura*, *Helichrysum ammitophilum*, *H. aureonitens*, *H. caespititium*, *H. cephaloideum*, *H. herbaceum*, *H. nudifolium* var. *nudifolium*, *H. nudifolium* var. *pilosellum*, *H. oreophilum*, *H. rugulosum*, *H. spiralepis*, *Hermannia depressa*, *Hirpicium armerioides*, *Ipomoea crassipes*, *I. pellita*, *Kohautia amatymbica*, *Lactuca inermis*, *Nolletia ciliaris*, *Pelargonium luridum*, *Pentanisia prunelloides* subsp. *prunelloides*, *Selago densiflora*, *S. galpinii*, *Senecio coronatus*, *S. erubescens* var. *crepidifolius*, *S. inornatus*, *Sonchus nanus*, *Tolpis capensis*, *Trifolium burchellianum*, *Vernonia natalensis*, *V. oligocephala*. Geophytic Herbs: *Boophone disticha*, *Crinum bulbispermum*, *Cyrtanthus stenanthus*, *Drimiopsis maculata*, *Eucomis autumnalis* subsp. *autumnalis*, *Gladiolus dalenii*, *G. papilio*, *Hypoxis rigidula* var. *pilosissima*, *Ledebouria ovatifolia*, *Watsonia lepida*, *Xysmalobium involucratum*, *X. undulatum*. Herbaceous Climber: *Rhynchosia totta*. Low Shrubs: *Helichrysum melanacme* (d), *Anthospermum rigidum* subsp. *pumilum*, *Euphorbia striata* var. *cuspidata*, *Gnidia kraussiana*, *Helichrysum dasycephalum*, *Polygala hottentotta*, *Tephrosia capensis* var. *acutifolia*.

Biogeographically Important Taxon (Low Escarpment endemic) Low Shrub: *Heteromma krookii*.

Conservation Endangered. Target 24%. Around 2% statutorily conserved in the Qwaqwa and Golden Gate Highlands National Parks as well as in the Sterkfontein Dam Nature Reserve. Almost half already transformed for cultivation (maize), building of dams (e.g. Sterkfontein, Loch Athlone, Saulspoort). *Cirsium vulgare*, *Cosmos bipinnatus* (forming spectacular displays along road verges and on old fields), *Hypochaeris radicata*, *Plantago virginica*, *Tagetes minuta*, *Verbena bonariensis*, *V. brasiliensis*, *Richardia brasiliensis*, *Guilleminea densa* and others are frequent alien invaders and diminish the agricultural and biodiversity value of these grasslands. Erosion low (44%), very low (22%), moderate (19%) or high (15%).

Remark The abundance of many species of *Helichrysum* is conspicuous.

References Scheepers (1975), Potgieter (1982), Du Preez (1991), Eckhardt (1993), Fuls (1993), Fuls et al. (1993a), Kay et al. (1993), Eckhardt et al. (1995), Smit et al. (1995c).

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Figure 8.41 Gm 4 Eastern Free State Sandy Grassland: Species-rich grassland with *Helichrysum psilolepis* (and other seven congeners) on the Qwaqwa Campus of the University of the Free State at Phuthaditjhaba (eastern Free State).

Gm 5 Basotho Montane Shrubland

VT 48 *Cymbopogon-Themeda* Veld (sandy) (58%) (Acocks 1953). LR 40 Moist Cold Highveld Grassland (67%) (Low & Rebelo 1996).

Distribution Free State Province, Lesotho and very marginally into KwaZulu-Natal Province: Foothills of the west-facing Drakensberg (also Maloti) and mainly on the slopes of mesas over a wide area

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Figure 8.42 Gm 5 Basotho Montane Shrubland: Mosaic of grassland and shrubland with *Euclea crispa* and *Diospyros austro-africana* (*Buddleja salviifolia* and *Myrsine africana* in deeper kloofs) on Clarens sandstone at the foot of the northern slopes of the Qwaqwa Mountain near Phuthaditjhaba (eastern Free State).

in the vicinity of Zastron in the southwest, the surrounds of Mafeteng, Hobhouse, Maseru, Roma, Ladybrand, Clocolan, Excelsior, Ficksburg, Butha-Buthe, Fouriesburg, Paul Roux, Bethlehem, Phuthaditjhaba as far as Harrismith in the northeast. This shrubland unit covers extensive areas in deeply incised river valleys of western Lesotho, especially those opening towards the south and west. Altitude 1 480–1 940 m.

Vegetation & Landscape Features Steep talus slopes and kloofs of the mesas and other mountain flanks supporting tall, in places very dense shrubland dominated by broad-leaved mesophyllous shrubs such as *Rhus erosa*, *Olea europaea* subsp. *africana*, *Euclea crispa* subsp. *crispa*, *Buddleja salviifolia*, *Leucosidea sericea*, *Rhus burchellii*, *Rhamnus prinoides*, *Scutia myrtina* and *Gymnopentzia buxifolia*. Mesas are often encircled by striking upper cliffs of Clarens Sandstone.

Geology & Soils The upper layers of the mudstones and sandstones of the Molteno, Elliot and Clarens Formations (Stormberg Group, Karoo Supergroup). The variations in weathering rates of the rocks resulted in the formation of numerous terraces along the slopes. In places the dolerite dykes cut through the thick sandstones, resulting in the formation of sheltered ravines. The soil surface is strewn with sandstone rocks and boulders. Ib land type, characterised by miscellaneous soil forms, specially the Mispah, and Glenrosa forms, is dominant. Other land types of minor occurrence are Fa, Bb and Db.

Climate This unit receives more than 720 mm of MAP. Wepener and Harrismith score 629 and 624 mm, respectively, while some patches found closer to the Maloti Mountain range (such as on Qwaqwa Mountain near Phuthaditjhaba) may receive more than 1 400 mm in particularly wet years. Most of the rain falls in summer and much of it as convectional rain, with torrential storms. The overall MAT is 13.7°C. Summers are wet and hot, while winters are (as a rule) dry and with frequent frost. Snowfall is a rare event. See also climate diagram for Gm 5 Basotho Montane Shrubland (Figure 8.36).

Important Taxa Tall Shrubs: *Buddleja salviifolia* (d), *Euclea crispa* subsp. *ovata* (d), *Olea europaea* subsp. *africana* (d), *Diospyros whyteana*, *Heteromorpha arborescens* var. *abyssinica*, *Leucosidea sericea*, *Rhamnus prinoides*, *Rhus dentata*, *Tarchonanthus minor*. Low Shrubs: *Anthospermum rigidum* subsp. *pumilum*, *Euphorbia striata* var. *cuspidata*, *Felicia filifolia* subsp. *filifolia*, *F. muricata*, *Gnidia capitata*, *Myrsine africana*. Graminoids: *Andropogon appendiculatus* (d), *A. schirensis* (d), *Aristida congesta* (d), *Cymbopogon pospischilii* (d), *Cynodon dactylon* (d), *Elionurus muticus* (d), *Eragrostis chloromelas* (d), *E. plana* (d), *E. racemosa* (d), *Heteropogon contortus* (d), *Hyparrhenia hirta* (d), *Microchloa caffra* (d), *Setaria sphacelata* (d), *Themeda triandra* (d), *Tristachya leucothrix* (d), *Aristida diffusa*, *Brachiaria serrata*, *Digitaria tricholaenoides*, *Eragrostis capensis*, *E. curvula*, *Harpochloa falx*, *Pennisetum sphacelatum*, *Setaria nigrirostris*. Herbs: *Ajuga ophrydis*, *Cineraria lyratiformis*, *Conyza podocephala*, *Dicoma anomala*, *Haplocarpha scaposa*, *Helichrysum caespititium*, *H. nudifolium* var. *nudifolium*, *H. rugulosum*, *Hermannia depressa*, *Hibiscus microcarpus*, *Ipomoea crassipes*, *Nolletia ciliaris*, *Pollichia campestris*, *Selago densiflora*, *Senecio erubescens* var. *crepidifolius*, *Tolpis capensis*, *Vernonia oligocephala*. Geophytic Herb: *Hypoxis rigidula* var. *pilosissima*. Herbaceous Climber: *Rhynchosia totta*.

Endemic Taxa Herbs: *Lessertia tenuifolia*, *Leucaena latisiliqua*.

Conservation Vulnerable. Target 28%. Only about 2% statutorily conserved in the Qwaqwa National Park, Golden Gate Highlands National Park and Sterkfontein Dam Nature Reserve. Erosion occurs at a wide range of intensity, including high (33%), moderate (26%) and very low (16%).

Remarks This shrubland unit is embedded in wet/moist grasslands such as the Eastern Free State Sandy Grassland and Zastron Moist Grassland. Locally, in deep, sheltered kloofs, this shrubland on rare occasions comes into contact with Northern Afrotemperate Forests. The unit includes the historically significant mesa of Thaba Bosiu in Lesotho.

References Müller (1986), Du Preez (1991), Du Preez & Bredenkamp (1991), Malan (1998), Malan et al. (1998, 1999), Müller (2002).

Gm 6 Frankfort Highveld Grassland

VT 53 *Themeda* Veld to *Cymbopogon–Themeda* Veld Transition (patchy) (79%) (Acocks 1953). LR 39 Moist Cool Highveld Grassland (95%) (Low & Rebelo 1996).

Distribution Free State and marginally Mpumalanga Provinces: Northeastern Free State—south and southeast of the Vaal Dam in the vicinity of Heilbron, Frankfort and Vrede. Altitude 1 460–1 800 m (mostly below 1 660 m).

Vegetation & Landscape Features Flat to slightly undulating and undulating terrain, with grassland dominated by *Eragrostis curvula* and *Themeda triandra*, accompanied by *E. capensis*, *E. plana*, *E. racemosa*, *Cymbopogon pospischilii*, *Elionurus muticus* and *Aristida junciformis*.

Geology & Soils Mudstone or shale with sandstone of the Adelaide Subgroup (Beaufort Group) with Jurassic Karoo dolerite intrusions. Soils are Glenrosa, Bonheim and Avalon, with Mayo forms dominating the outcrops and slightly elevated

areas, while the Sepane, Arcadia and Rensburg forms dominate the moist bottomlands. Much of the area (three quarters) is classified as Ea, while the rest is Ca land type.

Climate Summer-rainfall region, with MAP of 638 mm (much of which falls in the form of thunderstorms). MAT 14–15°C, indicating a cool to warm-temperature climate, characterised by great temperature differences between summer and winter (thermic continentality due to the deep-inland situation and high altitude of the unit). Occurrence of frost is frequent in winter. See also climate diagram for Gm 6 Frankfort Highveld Grassland (Figure 8.36).

P.J. du Preez

Figure 8.43 Gm 7 Northern Free State Shrubland: Shrubland on the slopes of a solitary koppie, Houtkop (1 751 m), south of Reitz (eastern Free State).

Important Taxa Graminoids: *Aristida bipartita* (d), *A. diffusa* (d), *Brachiaria serrata* (d), *Cymbopogon pospischilii* (d), *Cynodon dactylon* (d), *Digitaria tricholaenoides* (d), *Elionurus muticus* (d), *Eragrostis chloromelas* (d), *E. curvula* (d), *E. plana* (d), *E. racemosa* (d), *Harpochloa falx* (d), *Heteropogon contortus* (d), *Hyparrhenia hirta* (d), *Setaria nigrirostris* (d), *S. sphacelata* (d), *Themeda triandra* (d), *Tristachya leucothrix* (d), *Andropogon appendiculatus*, *Aristida congesta*, *A. junciformis* subsp. *galpinii*, *Cymbopogon caesius*, *Cynodon hirsutus*, *Diheteropogon amplectens*, *Eragrostis capensis*, *Helictotrichon turgidulum*, *Koeleria capensis*, *Melinis nerviglumis*, *Microchloa caffra*, *Panicum stapfianum*, *Pennisetum sphacelatum*. Herbs: *Dicoma anomala* (d), *Vernonia oligocephala* (d), *Berkheya onopordifolia* var. *onopordifolia*, *B. pinnatifida*, *Crabbea acaulis*, *Geigeria aspera* var. *aspera*, *Haplocarpha scaposa*, *Helichrysum nudifolium* var. *nudifolium*, *H. rugulosum*, *Hermannia depressa*, *Jamesbrittenia aurantiaca*, *Kohautia amatymbica*, *Rhynchosia effusa*, *Selago densiflora*. Geophytic Herbs: *Boophone disticha*, *Hypoxis rigidula* var. *pilosissima*. Herbaceous Climber: *Rhynchosia totta*. Low Shrubs: *Anthospermum hispidulum*, *A. rigidum* subsp. *pumilum*, *Berkheya annectens*, *Solanum panduriforme*.

Conservation Vulnerable. Target 24%. None conserved in statutory conservation areas. More than a third already transformed for cultivation (maize) or flooded by dams (Vaal Dam). Erosion is very low (95%).

References Eckhardt et al. (1993a, b), Fuls et al. (1993c).

Gm 7 Northern Free State Shrubland

VT 48 *Cymbopogon–Themeda* Veld (sandy) (40%), VT 53 *Themeda* Veld to *Cymbopogon–Themeda* Veld Transition (patchy) (34%) (Acocks 1953). LR 39 Moist Cool Highveld Grassland (89%) (Low & Rebelo 1996).

Distribution Free State Province and marginally also into Mpumalanga Province: Northeastern regions of the Free State in the surrounds of Lindley (southwest), Bethlehem, Reitz, Frankfort and Vrede (northeast). Altitude 1 460–1 800 m, mostly 1 540–1 640 m.

Vegetation & Landscape Features Mainly restricted (as isolated pockets) to south-facing slopes of koppies, butts and tafelbergs as well as steep slopes of deeply incised rivers, where sandstone outcrops occur. Typically a two-layered, closed-canopy shrubland dominated by tall shrubs such as *Rhamnus prinoides*, *Leucosidea sericea*, *Buddleja salviifolia*, *Rhus dentata*, *Euclea crispa* subsp. *crispa*, *Diospyros lycioides* and *Kiggelaria africana*. The lower layer is sparse grassland.

Geology & Soils Outcrops of especially Adelaide Subgroup (Beaufort Group, Karoo Supergroup) sandstones and to a lesser extent dolerite sills that protect sedimentary layers of sandstone, mudstone and siltstone from erosion. Soil forms that are typical of these rocky outcrops are the Glenrosa and Mispah forms. Ea land type is dominant (more than 50% of the area), accompanied by Dc and Bb.

Climate Summer-rainfall region, with 627 mm MAP. Much of the rainfall is convectional. The frost incidence is around 40 days. See also climate diagram for Gm 7 Northern Free State Shrubland (Figure 8.36).

Important Taxa Small Trees: *Kiggelaria africana* (d), *Cussonia paniculata*. Tall Shrubs: *Diospyros austro-africana* (d), *D. lycioides* subsp. *lycioides* (d), *Heteromorpha arborescens* var. *abyssinica* (d), *Leucosidea sericea* (d), *Rhamnus prinoides* (d), *Buddleja salviifolia*, *Calpurnia villosa*, *D. whyteana*, *Euclea crispa* subsp. *crispa*, *E. undulata*, *Grewia occidentalis*, *Melianthus dregeanus*, *Rhus dentata*, *R. pyroides*. Woody Climbers: *Asparagus asparagoides* (d), *Clematis oweniae*, *Dioscorea sylvatica*. Low Shrubs: *Anthospermum rigidum* subsp. *pumilum*, *Clutia affinis*, *C. hirsuta*, *C. pulchella*, *Euphorbia striata* var. *cuspidata*, *Felicia muricata*, *F. petiolata*, *Garuleum woodii*, *Indigofera filipes*, *I. woodii*, *Myrsine africana*, *Rhus discolor*, *Rubus rigidus*, *Senecio burchellii*, *S. harveianus*, *Solanum panduriforme*, *Sutera polelensis* subsp. *polelensis*. Succulent Shrub: *Crassula dependens*. Semiparasitic Shrub: *Osyris lanceolata*. Graminoids: *Elionurus muticus* (d), *Eragrostis chloromelas* (d), *Hyparrhenia hirta* (d), *Microchloa caffra* (d), *Themeda triandra* (d), *Aristida congesta*, *A. diffusa*, *A. junciformis* subsp. *galpinii*, *Brachiaria serrata*, *Cymbopogon pospischilii*, *Eragrostis capensis*, *E. curvula*, *E. gummiflua*, *E. plana*, *Harpochloa falx*, *Helictotrichon turgidulum*, *Heteropogon contortus*, *Koeleria capensis*, *Melinis nerviglumis*, *Panicum gilvum*, *Pennisetum sphacelatum*, *Schoenoxiphium rufum*, *Setaria sphacelata*, *Tragus racemosus*, *Tristachya leucothrix*. Herbs: *Ajuga ophrydis*, *Centella asiatica*, *Chamaesyce inaequilatera*, *Cineraria aspera*, *Commelina africana*, *Convolvulus dregeanus*, *Conyza podocephala*, *Cyathula cylindrica*, *Erucastrum austroafricanum*, *Geranium schlechteri*, *Helichrysum cephaloideum*, *H. rugulosum*,

Hermannia depressa, *Hibiscus aethiopicus* var. *ovatus*, *Lactuca inermis*, *Pollichia campestris*, *Pseudognaphalium undulatum*, *Rubia horrida*, *Salvia runcinata*, *Senecio hieracioides*, *S. isatideus*, *Solanum retroflexum*, *Stachys hyssopoides*, *S. natalensis*, *Trifolium africanum*, *Vernonia natalensis*. Geophytic Herbs: *Agapanthus campanulatus*, *Asclepias multicaulis*, *Cheilanthes quadripinnata*, *Eucomis autumnalis* subsp. *autumnalis*, *Hypoxis hemerocallidea*, *Mohria caffrorum*, *Oxalis corniculata*, *Pellaea calomelanos*, *Zantedeschia albomaculata* subsp. *albomaculata*. Succulent Herbs: *Crassula lanceolata*, *C. setulosa* var. *setulosa*.

Conservation Least threatened. Target 28%. None conserved in statutory conservation areas. Erosion very low (65%), low (23%) and moderate (12%).

References Fuls (1993), Fuls et al. (1993a, b), Eckhardt et al. (1997).

Gm 8 Soweto Highveld Grassland

VT 52 *Themeda* Veld (Turf Highveld) (56%) (Acocks 1953). LR 35 Moist Clay Highveld Grassland (51%) (Low & Rebelo 1996).

Distribution Mpumalanga, Gauteng (and to a very small extent also in neighbouring Free State and North-West) Provinces: In a broad band roughly delimited by the N17 road between Ermelo and Johannesburg in the north, Perdekop in the southeast and the Vaal River (border with the Free State) in the south. It extends further westwards along the southern edge of the Johannesburg Dome (including part of Soweto) as far as the vicinity of Randfontein. In southern Gauteng it includes the surrounds of Vanderbijlpark and Vereeniging as well as Sasolburg in the northern Free State. Altitude 1 420–1 760 m.

Vegetation & Landscape Features Gently to moderately undulating landscape on the Highveld plateau supporting short to medium-high, dense, tufted grassland dominated almost entirely by *Themeda triandra* and accompanied by a variety of other grasses such as *Elionurus muticus*, *Eragrostis racemosa*, *Heteropogon contortus* and *Tristachya leucothrix*. In places not disturbed, only scattered small wetlands, narrow stream alluvia, pans and occasional ridges or rocky outcrops interrupt the continuous grassland cover.

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Figure 8.44 Gm 8 Soweto Highveld Grassland: Typical mesic highveld grassland with *Themeda triandra* and several *Eragrostis* species still found in some parts of southern Gauteng in natural condition.

Geology and Soils Shale, sandstone or mudstone of the Madzaringwe Formation (Karoo Supergroup) or the intrusive Karoo Suite dolerites which feature prominently in the area. In the south, the Volksrust Formation (Karoo Supergroup) is found and in the west, the rocks of the older Transvaal, Ventersdorp and Witwatersrand Supergroups are most significant. Soils are deep, reddish on flat plains and are typically Ea, Ba and Bb land types.

Climate Summer-rainfall region (MAP 662 mm). Cool-temperate climate with thermic continentality (high extremes between maximum summer and minimum winter temperatures, frequent occurrence of frost, large thermic diurnal differences, especially in autumn and spring). See also climate diagram for Gm 8 Soweto Highveld Grassland (Figure 8.36).

Important Taxa Graminoids: *Andropogon appendiculatus* (d), *Brachiaria serrata* (d), *Cymbopogon pospischilii* (d), *Cynodon dactylon* (d), *Elionurus muticus* (d), *Eragrostis capensis* (d), *E. chloromelas* (d), *E. curvula* (d), *E. plana* (d), *E. planiculmis* (d), *E. racemosa* (d), *Heteropogon contortus* (d), *Hyparrhenia hirta* (d), *Setaria nigrirostris* (d), *S. sphacelata* (d), *Themeda triandra* (d), *Tristachya leucothrix* (d), *Andropogon schirensis*, *Aristida adscensionis*, *A. bipartita*, *A. congesta*, *A. junciformis* subsp. *galpinii*, *Cymbopogon caesius*, *Digitaria diagonalis*, *Diheteropogon amplectens*, *Eragrostis micrantha*, *E. superba*, *Harpochloa falx*, *Microchloa caffra*, *Paspalum dilatatum*. Herbs: *Hermannia depressa* (d), *Acalypha angustata*, *Berkheya setifera*, *Dicoma anomala*, *Euryops gilfillanii*, *Geigeria aspera* var. *aspera*, *Graderia subintegra*, *Haplocarpha scaposa*, *Helichrysum miconiifolium*, *H. nudifolium* var. *nudifolium*, *H. rugulosum*, *Hibiscus pusillus*, *Justicia anagalloides*, *Lippia scaberrima*, *Rhynchosia effusa*, *Schistostephium crataegifolium*, *Selago densiflora*, *Senecio coronatus*, *Vernonia oligocephala*, *Wahlenbergia undulata*. Geophytic Herbs: *Haemanthus humilis* subsp. *hirsutus*, *H. montanus*. Herbaceous Climber: *Rhynchosia totta*. Low Shrubs: *Anthospermum hispidulum*, *A. rigidum* subsp. *pumilum*, *Berkheya annectens*, *Felicia muricata*, *Ziziphus zeyheriana*.

Conservation Endangered. Target 24%. Only a handful of patches statutorily conserved (Waldrift, Krugersdorp, Leeuwkuil, Suikerbosrand, Rolfe's Pan Nature Reserves) or privately conserved (Johanna Jacobs, Tweefontein, Gert Jacobs, Nikolaas and Avalon Nature Reserves, Heidelberg Natural Heritage Site). Almost half of the area already transformed by cultivation, urban sprawl, mining and building of road infrastructure. Some areas have been flooded by dams (Grootdraai, Leeukuil, Trichardtsfontein, Vaal, Willem Brummer). Erosion is generally very low (93%).

References Bredenkamp (1975, 1976, 1977), Bredenkamp & Theron (1978), Bezuidenhout & Bredenkamp (1991a).

Gm 9 Tsakane Clay Grassland

VT 48 *Cymbopogon-Themeda* Veld (sandy) (58%) (Acocks 1953). LR 39 Moist Cool Highveld Grassland (64%) (Low & Rebelo 1996).

Distribution Gauteng and Mpumalanga Provinces: In patches extending in a narrow band from Soweto to Springs, broadening southwards to Nigel and from there towards Vereeniging, as well

as north of the Vaal Dam and between Balfour and Standerton (including Willemsdal). Altitude 1 480–1 680 m.

Vegetation & Landscape Features Flat to slightly undulating plains and low hills. Vegetation is short, dense grassland dominated by a mixture of common highveld grasses such as *Themeda triandra*, *Heteropogon contortus*, *Elionurus muticus* and a number of *Eragrostis* species. Most prominent forbs are of the families Asteraceae, Rubiaceae, Malvaceae, Lamiaceae and Fabaceae. Disturbance leads to an increase in the abundance of the grasses *Hyparrhenia hirta* and *Eragrostis chloromelas*.

Geology & Soils The most significant rock is the basaltic lava of the Klipriviersberg Group (Ventersdorp Supergroup), together with the sedimentary rocks of the Madzaringwe Formation of the Karoo Supergroup. Soils typical of Ba and Bb land types.

Climate Strongly seasonal summer rainfall, with very dry winters. MAP 630–720 mm. The overall MAT of 15°C indicates a transition between a cool-temperate and warm-temperate climate. The incidence of frost frequent, increasing towards the southeast. See also climate diagram for Gm 9 Tsakane Clay Grassland (Figure 8.36).

Important Taxa Graminoids: *Brachiaria serrata* (d), *Cynodon dactylon* (d), *C. hirsutus* (d), *Digitaria ternata* (d), *Elionurus muticus* (d), *Eragrostis chloromelas* (d), *E. patentipilosa* (d), *E. plana* (d), *E. racemosa* (d), *Heteropogon contortus* (d), *Hyparrhenia hirta* (d), *Microchloa caffra* (d), *Setaria sphacelata* (d), *Themeda triandra* (d), *Trachypogon spicatus* (d), *Abildgaardia ovata*, *Andropogon schirensis*, *Cymbopogon caesius*, *Diheteropogon amplectens*, *Melinis nerviglumis*, *Panicum gilvum*, *Setaria nigrirostris*. Herbs: *Acanthospermum australe*, *Ajuga ophrydis*, *Eriosema salignum*, *Euryops transvaalensis* subsp. *transvaalensis, Gerbera viridifolia*, *Helichrysum nudifolium* var. *nudifolium*, *H. rugulosum*, *Hermannia depressa*, *Lotononis macrosepala*, *Nidorella hottentotica*, *Pentanisia prunelloides* subsp. *latifolia*, *Peucedanum caffrum*, *Rotheca hirsuta*, *Selago paniculata*, *Senecio coronatus*, *S. inornatus*, *Sonchus nanus*, *Vernonia oligocephala*. Geophytic Herbs: *Aspidoglossum ovalifolium*, *Hypoxis rigidula* var. *pilosissima*. Semiparasitic Herb: *Striga asiatica*. Low Shrubs: *Anthospermum rigidum* subsp. *pumilum*, *Chaetacanthus setiger*, *Tephrosia capensis* var. *acutifolia*. Semiparasitic Shrub: *Thesium impeditum*.

Conservation Endangered. Target 24%. Only 1.5% conserved in statutory reserves (Suikerbosrand, Olifantsvlei, Klipriviersberg, Marievale) and a small portion also in private nature reserves (Avalon, Ian P. Coetser, Andros). More than 60% transformed by cultivation, urbanisation, mining, dam-building and roads. Large portions of Alberton, Springs, Tsakane and part of Soweto (all south and east of Johannesburg) were built in the area of this vegetation unit. Urbanisation is increasing and further expansion of especially the southern suburbs of Johannesburg and the towns of the East Rand (especially the Brakpan District) will bring further pressure on the remaining vegetation. Erosion very low (87%) and low (11%) across the entire unit.

Remark 1 Grasslands in a part of this unit have been described as *Helichrysum rugulosum–Conyza podocephala* Grassland by Coetzee et al. (1995).

Remark 2 The unit contains a number of small pans, many of which have been disturbed, drained or are overgrazed and trampled.

References Acocks (1953, 1988), Bredenkamp (1975, 1976, 1977), Bredenkamp & Theron (1980), Coetzee et al. (1995).

Gm 10 Egoli Granite Grassland

VT 61 Bankenveld (100%) (Acocks 1953). LR 34 Rocky Highveld Grassland (100%) (Low & Rebelo 1996).

Distribution Gauteng Province: Johannesburg Dome extending in the region between northern Johannesburg in the south, and from near Lanseria Airport and Centurion (south of Pretoria) to the north, westwards to about Muldersdrif and eastwards to Tembisa. Altitude 1 280–1 660 m.

Vegetation & Landscape Features Moderately undulating plains and low hills supporting tall, usually *Hyparrhenia hirta*-dominated grassland, with some woody species on rocky outcrops or rock sheets. The rocky habitats show a high diversity of woody species, which occur in the form of scattered shrub groups or solitary small trees.

Geology & Soils Archaean granite and gneiss of the Halfway House Granite at the core of the Johannesburg Dome supporting leached, shallow, coarsely grained, sandy soil poor in nutrients of Glenrosa form. Small area is built by ultramafics. Dominant land types Bb and Ba.

Climate Strongly seasonal summer-rainfall region, with very dry winters. MAP 620–800 mm (overall average 680 mm). The coefficient of variation in MAP from 24–27% across the unit. Incidence of frost frequent, but higher in the south than the north. See also climate diagram for Gm 10 Egoli Granite Grassland (Figure 8.36).

Important Taxa Graminoids: *Aristida canescens* (d), *A. congesta* (d), *Cynodon dactylon* (d), *Digitaria monodactyla* (d), *Eragrostis capensis* (d), *E. chloromelas* (d), *E. curvula* (d), *E. racemosa* (d), *Heteropogon contortus* (d), *Hyparrhenia hirta*

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Figure 8.45 Gm 10 Egoli Granite Grassland: Rocky outcrop at Knoppieslaagte, west of Valhalla near Centurion (Gauteng) with *Aloe greatheadii*, *Hypoxis rigidula*, *Pygmaeothamnus zeyheri*, *Thesium magalismontanum* and *Crassula capitella* and grasses such as *Elionurus muticus*, *Tristachya leucothrix*, *Melinis repens* and *Trachypogon spicatus*.

(d), *Melinis repens* subsp. *repens* (d), *Monocymbium ceresiiforme* (d), *Setaria sphacelata* (d), *Themeda triandra* (d), *Tristachya leucothrix* (d), *Andropogon eucomus*, *Aristida aequiglumis*, *A. diffusa*, *A. scabrivalvis* subsp. *borumensis*, *Bewsia biflora*, *Brachiaria serrata*, *Bulbostylis burchellii*, *Cymbopogon caesius*, *Digitaria tricholaenoides*, *Diheteropogon amplectens*, *Eragrostis gummiflua*, *E. sclerantha*, *Panicum natalense*, *Schizachyrium sanguineum*, *Setaria nigrirostris*, *Tristachya rehmannii*, *Urelytrum agropyroides*. Herbs: *Acalypha angustata*, *A. peduncularis*, *Becium obovatum*, *Berkheya insignis*, *Crabbea hirsuta*, *Cyanotis speciosa*, *Dicoma anomala*, *Helichrysum rugulosum*, *Justicia anagalloides*, *Kohautia amatymbica*, *Nidorella hottentotica*, *Pentanisia prunelloides* subsp. *latifolia*, *Pseudognaphalium luteo-album*, *Senecio venosus*. Geophytic Herbs: *Cheilanthes deltoidea*, *C. hirta*. Small Tree: *Vangueria infausta*. Tall Shrub: *Rhus pyroides*. Low Shrubs: *Anthospermum hispidulum*, *A. rigidum* subsp. *pumilum*, *Gnidia capitata*, *Helichrysum kraussii*, *Ziziphus zeyheriana*. Succulent Shrub: *Lopholaena coriifolia*.

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Figure 8.46 Gm 11 Rand Highveld Grassland: Grasslands south of Bronkhorstspruit (Mpumalanga) dominated by grasses such as *Themeda triandra*, *Elionurus muticus*, *Diheteropogon amplectens* and *Tristachya leucothrix*.

Conservation Endangered. Target 24%. Only about 3% of this unit is conserved in statutory reserves (Diepsloot and Melville Koppies Nature Reserves) and a number of private conservation areas including Motsetse and Isaac Stegmann Nature Reserves, Kingskloof Natural Heritage Site, Melrose and Beaulieu Bird Sanctuaries as well as the Walter Sisulu National Botanical Garden. More than two thirds of the unit has already undergone transformation mostly by urbanisation, cultivation or by building of roads. Current rates of transformation threaten most of the remaining unconserved areas. There is no serious alien infestation in this unit, although species such as *Eucalyptus grandis*, *E. camaldulensis* and *E. sideroxylon* are commonly found. Erosion is moderate and very low.

Remark 1 This grassland is considered by some to be primary, though is heavily utilised, poor in species and degraded, and often resembles secondary grassland that developed on old fields.

Remark 2 So-called Witwatersrand serpentine sourveld (Reddy et al. 2001)—rocky grasslands on ultramafic rocks of a greenstone belt of uncertain origin—falls within this vegetation unit. Unlike in the Barberton region (see SVl 13 Barberton Serpentine Sourveld), the floristic composition of the Witwatersrand serpentines does not support separation of the ultramafic sourveld as a separate unit. So far no endemic taxa have been discovered on the Witwatersrand serpentines, the floristic composition of which is similar to that of the surrounding granite grassland.

References Acocks (1953, 1988), Grobler (2000), Ellery et al. (2001), Reddy et al. (2001).

Gm 11 Rand Highveld Grassland

VT 61 Bankenveld (64%) (Acocks 1953). LR 34 Rocky Highveld Grassland (45%), LR 38 Moist Sandy Highveld Grassland (21%) (Low & Rebelo 1996).

Distribution Gauteng, North-West, Free State and Mpumalanga Provinces: In areas between rocky ridges from Pretoria to Witbank, extending onto ridges in the Stoffberg and Roossenekal regions as well as west of Krugersdorp centred in the vicinity of Derby and Potchefstroom, extending southwards and northeastwards from there. Altitude 1 300–1 635 m, but reaches 1 760 m in places.

Vegetation & Landscape Features Highly variable landscape with extensive sloping plains and a series of ridges slightly elevated over undulating surrounding plains. The vegetation is species-rich, wiry, sour grassland alternating with low, sour shrubland on rocky outcrops and steeper slopes. Most common grasses on the plains belong to the genera *Themeda*, *Eragrostis*, *Heteropogon* and *Elionurus*. High diversity of herbs, many of which belong to the Asteraceae, is also a typical feature. Rocky hills and ridges carry sparse (savannoid) woodlands with *Protea caffra* subsp. *caffra*, *P. welwitschii*, *Acacia caffra* and *Celtis africana*, accompanied by a rich suite of shrubs among which the genus *Rhus* (especially *R. magalismonata*) is most prominent.

Geology & Soils Quartzite ridges of the Witwatersrand Supergroup and the Pretoria Group as well as the Selons River Formation of the Rooiberg Group (last two are of the Transvaal Supergroup), supporting soils of various quality (shallow Glenrosa and Mispah forms especially on rocky ridges), typical of Ba, Bc, Bb and Ib land types.

Climate Strongly seasonal summer-rainfall, warm-temperate region, with very dry winters. MAP is 654 mm, ranging between 570 mm and 730 mm, slightly lower in the western regions. The coefficient of variation of MAP is 28% in the west and 26–27% in the east, and varies only slightly from 25% to 29% across the unit. The incidence of frost is higher in the west (30–40 days) than in the east (10–35 days). See also climate diagram for Gm 11 Rand Highveld Grassland (Figure 8.36).

Important Taxa Graminoids: *Ctenium concinnum* (d), *Cynodon dactylon* (d), *Digitaria monodactyla* (d), *Diheteropogon amplectens* (d), *Eragrostis chloromelas* (d), *Heteropogon contortus* (d), *Loudetia simplex* (d), *Monocymbium ceresiiforme* (d), *Panicum natalense* (d), *Schizachyrium sanguineum* (d), *Setaria sphacelata* (d), *Themeda triandra* (d), *Trachypogon spicatus* (d), *Tristachya biseriata* (d), *T. rehmannii* (d), *Andropogon schirensis*, *Aristida aequiglumis*, *A. congesta*, *A. junciformis* subsp. *galpinii*, *Bewsia biflora*, *Brachiaria nigropedata*, *B. serrata*, *Bulbostylis burchellii*, *Cymbopogon caesius*, *Digitaria tricholaenoides*, *Elionurus muticus*, *Eragrostis capensis*, *E. curvula*, *E. gummiflua*, *E. plana*,

E. racemosa, *Hyparrhenia hirta*, *Melinis nerviglumis*, *M. repens* subsp. *repens*, *Microchloa caffra*, *Setaria nigrirostris*, *Sporobolus pectinatus*, *Trichoneura grandiglumis*, *Urelytrum agropyroides*. Herbs: *Acanthospermum australe* (d), *Justicia anagalloides* (d), *Pollichia campestris* (d), *Acalypha angustata*, *Chamaecrista mimosoides*, *Dicoma anomala*, *Helichrysum caespititium*, *H. nudifolium* var. *nudifolium*, *H. rugulosum*, *Ipomoea crassipes*, *Kohautia amatymbica*, *Lactuca inermis*, *Macledium zeyheri* subsp. *argyrophylum*, *Nidorella hottentotica*, *Oldenlandia herbacea*, *Rotheca hirsuta*, *Selago densiflora*, *Senecio coronatus*, *Sonchus dregeanus*, *Vernonia oligocephala*, *Xerophyta retinervis*. Geophytic Herbs: *Boophone disticha*, *Cheilanthes hirta*, *Haemanthus humilis* subsp. *humilis*, *Hypoxis rigidula* var. *pilosissima*, *Ledebouria ovatifolia*, *Oxalis corniculata*. Succulent Herb: *Aloe greatheadii* var. *davyana*. Low Shrubs: *Anthospermum rigidum* subsp. *pumilum*, *Indigofera comosa*, *Rhus magalismontana, Stoebe plumosa*. Succulent Shrub: *Lopholaena coriifolia* (d). Geoxylic Suffrutex: *Elephantorrhiza elephantina*.

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Figure 8.47 Gm 12 Eastern Highveld Grassland: Grasslands of the Warburton area (Mpumalanga) with species of *Berkheya* and *Ipomoea* prominent in the foreground.

Biogeographically Important Taxa (all Northern sourveld endemics) Geophytic Herbs: *Agapanthus inapertus* subsp. *pendulus*, *Eucomis vandermerwei*. Succulent Herb: *Huernia insigniflora*. Low Shrub: *Melhania randii*.

Endemic Taxa Herbs: *Melanospermum rudolfii*, *Polygala spicata*. Succulent Herbs: *Anacampseros subnuda* subsp. *lubbersii*, *Frithia humilis*. Succulent Shrubs: *Crassula arborescens* subsp. *undulatifolia*, *Delosperma purpureum*. Small Trees: *Encephalartos lanatus*, *E. middelburgensis*.

Conservation Endangered. Target 24%. Poorly conserved (only 1%). Small patches protected in statutory reserves (Kwaggavoetpad, Van Riebeeck Park, Bronkhorstspruit, Boskop Dam Nature Reserves) and in private conservation areas (e.g. Doornkop, Zemvelo, Rhenosterpoort and Mpopomeni). Almost half has been transformed mostly by cultivation, plantations, urbanisation or dam-building. Cultivation may also have had an impact on an additional portion of the surface area of the unit where old lands are currently classified as grasslands in land-cover classifications and poor land management has led to degradation of significant portions of the remainder of this unit (D.B. Hoare, personal observation). Scattered aliens (most prominently *Acacia mearnsii*) occur in about 7% of this unit. Only about 7% has been subjected to moderate to high erosion levels.

Remark This vegetation unit is very varied and geographically disjunct and requires further investigation.

References Acocks (1953, 1988), Bezuidenhout (1988), Bezuidenhout & Bredenkamp (1991b), Coetzee (1993), Coetzee et al. (1994, 1995), Smit et al. (1997), Burgoyne et al. (2000), Grobler (2000), Grobler et al. (2006).

Gm 12 Eastern Highveld Grassland

VT 61 Bankenveld (42%), VT 57 North-Eastern Sandy Highveld (33%) (Acocks 1953). LR 38 Moist Sandy Highveld Grassland (69%) (Low & Rebelo 1996).

Distribution Mpumalanga and Gauteng Provinces: Plains between Belfast in the east and the eastern side of Johannesburg in the west and extending southwards to Bethal, Ermelo and west of Piet Retief. Altitude 1 520–1 780 m, but also as low as 1 300 m.

Vegetation & Landscape Features Slightly to moderately undulating plains, including some low hills and pan depressions. The vegetation is short dense grassland dominated by the usual highveld grass composition (*Aristida*, *Digitaria*, *Eragrostis*, *Themeda*, *Tristachya* etc.) with small, scattered rocky outcrops with wiry, sour grasses and some woody species (*Acacia caffra*, *Celtis africana*, *Diospyros lycioides* subsp *lycioides*, *Parinari capensis*, *Protea caffra*, *P. welwitschii* and *Rhus magalismontanum*).

Geology & Soils Red to yellow sandy soils of the Ba and Bb land types found on shales and sandstones of the Madzaringwe Formation (Karoo Supergroup). Land types Bb (65%) and Ba (30%).

Climate Strongly seasonal summer rainfall, with very dry winters. MAP 650–900 mm (overall average: 726 mm), MAP relatively uniform across most of this unit, but increases significantly in the extreme southeast. The coefficient of variation in MAP is 25% across most of the unit, but drops to 21% in the east and southeast. Incidence of frost from 13–42 days, but higher at higher elevations. See also climate diagram for Gm 12 Eastern Highveld Grassland (Figure 8.36).

Important Taxa Graminoids: *Aristida aequiglumis* (d), *A. congesta* (d), *A. junciformis* subsp. *galpinii* (d), *Brachiaria serrata* (d), *Cynodon dactylon* (d), *Digitaria monodactyla* (d), *D. tricholaenoides* (d), *Elionurus muticus* (d), *Eragrostis chloromelas* (d), *E. curvula* (d), *E. plana* (d), *E. racemosa* (d), *E. sclerantha* (d), *Heteropogon contortus* (d), *Loudetia simplex* (d), *Microchloa caffra* (d), *Monocymbium ceresiiforme* (d), *Setaria sphacelata* (d), *Sporobolus africanus* (d), *S. pectinatus* (d), *Themeda triandra* (d), *Trachypogon spicatus* (d), *Tristachya leucothrix* (d), *T. rehmannii* (d), *Alloteropsis semialata* subsp. *eckloniana*, *Andropogon appendiculatus*, *A. schirensis*, *Bewsia biflora*, *Ctenium concinnum*, *Diheteropogon amplectens*, *Eragrostis capensis*, *E. gummiflua*, *E. patentissima*, *Harpochloa falx*, *Panicum natalense*, *Rendlia altera*, *Schizachyrium sanguineum*, *Setaria nigrirostris*, *Urelytrum agropyroides*. Herbs: *Berkheya setifera* (d), *Haplocarpha scaposa* (d), *Justicia anagalloides* (d), *Pelargonium luridum* (d), *Acalypha angustata*, *Chamaecrista*

mimosoides, *Dicoma anomala*, *Euryops gilfillanii*, *E. transvaalensis* subsp. *setilobus*, *Helichrysum aureonitens*, *H. caespititium*, *H. callicomum*, *H. oreophilum*, *H. rugulosum*, *Ipomoea crassipes*, *Pentanisia prunelloides* subsp. *latifolia*, *Selago densiflora*, *Senecio coronatus*, *Vernonia oligocephala*, *Wahlenbergia undulata*. Geophytic Herbs: *Gladiolus crassifolius*, *Haemanthus humilis* subsp. *hirsutus*, *Hypoxis rigidula* var. *pilosissima*, *Ledebouria ovatifolia*. Succulent Herb: *Aloe ecklonis*. Low Shrubs: *Anthospermum rigidum* subsp. *pumilum*, *Stoebe plumosa*.

Conservation Endangered. Target 24%. Only very small fraction conserved in statutory reserves (Nooitgedacht Dam and Jericho Dam Nature Reserves) and in private reserves (Holkranse, Kransbank, Morgenstond). Some 44% transformed primarily by cultivation, plantations, mines, urbanisation and by building of dams. Cultivation may have had a more extensive impact, indicated by land-cover data. No serious alien invasions are reported, but *Acacia mearnsii* can become dominant in disturbed sites. Erosion is very low.

References Acocks (1953, 1988), Turner (1989), Coetzee (1993), Coetzee et al. (1994, 1995), Smit et al. (1997).

A. Lindström

Figure 8.48 Gm 13 Amersfoort Highveld Clay Grassland: Short grasslands with *Themeda triandra* and various *Helichrysum* species in the area between Volksrust and Ermelo (Mpumalanga).

Gm 13 Amersfoort Highveld Clay Grassland

VT 54 *Themeda* Veld to Highland Sourveld Transition (43%), VT 57 North-Eastern Sandy Highveld (29%) (Acocks 1953). LR 41 Wet Cold Highveld Grassland (30%), LR 38 Moist Sandy Highveld Grassland (29%) (Low & Rebelo 1996).

Distribution Mpumalanga and KwaZulu-Natal Provinces: This unit extends in a north-south band from just south of Ermelo, down through Amersfoort to the Memel area in south. Altitude 1 580–1 860 m.

Vegetation & Landscape Features Comprised of undulating grassland plains, with small scattered patches of dolerite outcrops in areas. The vegetation is comprised of a short closed grassland cover, largely dominated by a dense *Themeda triandra* sward, often severely grazed to form a short lawn.

Geology & Soils Restricted to vertic clay soils derived from dolerite that is intrusive in the Karoo sediments of the Madzaringwe Formation in the north and the Volksrust Formation and the Adelaide Subgroup in the south. Dominant land type Ca, while Ea land type is of subordinate importance.

Climate Rainfall mainly in early summer, from 620 mm in the west to 830 mm in the east (MAP 694 mm). MAT 14ºC, with temperatures higher in the west than the east. Winters are cold and summers are mild. Incidence of frost very high. Also see climate diagram for Gm 13 Amersfoort Highveld Clay Grassland (Figure 8.36).

Important Taxa Graminoids: *Andropogon appendiculatus* (d), *Brachiaria serrata* (d), *Digitaria monodactyla* (d), *D. tricholaenoides* (d), *Elionurus muticus* (d), *Eragrostis capensis* (d), *E. chloromelas* (d), *E. plana* (d), *E. racemosa* (d), *Harpochloa falx* (d), *Heteropogon contortus* (d), *Microchloa caffra* (d), *Panicum natalense* (d), *Setaria nigrirostris* (d), *S. sphacelata* (d), *Themeda triandra* (d), *Trichoneura grandiglumis* (d), *Tristachya leucothrix* (d), *Abildgaardia ovata*, *Andropogon schirensis*, *Aristida bipartita*, *A. congesta*, *A. junciformis* subsp. *galpinii*, *A. stipitata* subsp. *graciliflora*, *Bulbostylis contexta*, *Chloris virgata*, *Cymbopogon caesius*, *C. pospischilii*, *Cynodon dactylon*, *Digitaria diagonalis*, *D. ternata*, *Diheteropogon amplectens*, *Eragrostis curvula*, *Koeleria capensis*, *Panicum coloratum*, *Setaria incrassata*. Herbs: *Berkheya setifera* (d), *Vernonia natalensis*, *V. oligocephala* (d), *Acalypha peduncularis*, *A. wilmsii*, *Berkheya insignis*, *B. pinnatifida*, *Crabbea acaulis*, *Cynoglossum hispidum*, *Dicoma anomala*, *Haplocarpha scaposa*, *Helichrysum caespititium*, *H. rugulosum*, *Hermannia coccocarpa*, *H. depressa*, *H. transvaalensis*, *Ipomoea crassipes*, *I. oblongata*, *Jamesbrittenia silenoides*, *Pelargonium luridum*, *Pentanisia prunelloides* subsp. *latifolia*, *Peucedanum magalismontanum*, *Pseudognaphalium luteo-album*, *Rhynchosia effusa*, *Salvia repens*, *Schistostephium crataegifolium*, *Sonchus nanus*, *Wahlenbergia undulata*. Herbaceous Climber: *Rhynchosia totta*. Geophytic Herbs: *Boophone disticha*, *Eucomis autumnalis* subsp. *clavata*, *Hypoxis villosa* var. *obliqua*, *Zantedeschia albomaculata* subsp. *macrocarpa*. Tall Shrubs: *Diospyros austro-africana*, *D. lycioides* subsp. *guerkei*. Low Shrubs: *Anthospermum rigidum* subsp. *pumilum* (d), *Helichrysum melanacme* (d), *Chaetacanthus costatus*, *Euphorbia striata* var. *cuspidata*, *Gnidia burchellii*, *G. capitata*, *Polygala uncinata*, *Rhus discolor*. Succulent Shrub: *Euphorbia clavarioides* var. *truncata*.

Conservation Vulnerable. The conservation target is 27% but none is protected. Some 25% of unit is transformed, predominantly by cultivation (22%). The area is not suited to afforestation. Silver and black wattle (*Acacia* species), and *Salix babylonica* invade drainage areas. Erosion potential is very low (57%) and low (40%).

Remarks Overgrazing leads to invasion of *Stoebe vulgaris* (aptly named bankrupt bush). Parts of this unit were once cultivated and now lie fallow and have been left to re-vegetate with pioneer species. These transformed areas are not picked up by satellite for transformation coverage and the percentage of grasslands still in a natural state may be underestimated.

References Acocks (1953, 1988), Breytenbach (1991), Smit (1992), Breytenbach et al. (1993), Smit et al. (1995a, c).

Gm 14 Wakkerstroom Montane Grassland

VT 57 North-Eastern Sandy Highveld (57%) (Acocks 1953). LR 38 Moist Sandy Highveld Grassland (49%), LR 41 Wet Cold Highveld Grassland (27%) (Low & Rebelo 1996).

Distribution KwaZulu-Natal and Mpumalanga Provinces: Occurring from the Escarpment just north of Sheepmoor (north), to southeast of Utrecht, and then from the vicinity of Volksrust in the west to Mandhlangampisi Mountain near Luneburg in the east. Altitude 1 440–2 200 m.

Vegetation & Landscape Features This unit is a less obvious continuation of the Escarpment that links the southern and northern Drakensberg escarpments. It straddles this divide and is comprised of low mountains and undulating plains. The vegetation comprises predominantly short montane grasslands on the plateaus and the relatively flat areas, with short forest and *Leucosidea* thickets occurring along steep, mainly east-facing slopes and drainage areas. *L. sericea* is the dominant woody pioneer species that invades areas as a result of grazing mismanagement.

Geology & Soils The mudstones, sandstones and shale of the Madzaringwe and Volksrust Formations (Karoo Supergroup) were intruded by voluminous Jurassic dolerite dykes and sills. Ac land type dominant, while Fa and Ca are of subordinate importance.

Climate Rainfall peaks in midsummer. Rainfall 800–1 250 mm per year (MAP 902 mm). This unit experiences an orographic effect which results in a locally higher precipitation than the adjacent areas. Winters very cold and summers mild (MAT 14°C). See also climate diagram for Gm 14 Wakkerstroom Montane Grassland (Figure 8.36).

Important Taxa Small Trees: *Canthium ciliatum*, *Protea subvestita*. Tall Shrubs: *Buddleja salviifolia* (d), *Leucosidea sericea* (d), *Buddleja auriculata*, *Diospyros lycioides* subsp. *guerkei*, *Euclea crispa* subsp. *crispa*, *Rhus montana*, *R. rehmanniana*, *R. transvaalensis*. Low Shrubs: *Asparagus devenishii* (d), *Cliffortia linearifolia* (d), *Helichrysum melanacme* (d), *H. splendidum* (d), *Anthospermum rigidum* subsp. *pumilum*, *Clutia natalensis*, *Erica oatesii*, *Felicia filifolia* subsp. *filifolia*, *Gymnosporia heterophylla*, *Helichrysum hypoleucum*, *Hermannia geniculata*, *Inulanthera dregeana*, *Metalasia densa*, *Printzia pyrifolia*, *Rhus discolor*, *Rubus ludwigii* subsp. *ludwigii*. Graminoids: *Andropogon schirensis* (d), *Ctenium concinnum* (d), *Cymbopogon caesius* (d), *Digitaria tricholaenoides* (d), *Diheteropogon amplectens* (d), *Eragrostis chloromelas* (d), *E. plana* (d), *E. racemosa* (d), *Harpochloa falx* (d), *Heteropogon contortus* (d), *Hyparrhenia hirta* (d), *Microchloa caffra* (d), *Themeda triandra* (d), *Trachypogon spicatus* (d), *Tristachya leucothrix* (d), *Alloteropsis semialata* subsp. *eckloniana*, *Aristida junciformis* subsp. *galpinii*, *Brachiaria serrata*, *Diheteropogon filifolius*, *Elionurus muticus*, *Eragrostis capensis*, *Eulalia villosa*, *Festuca scabra*, *Loudetia simplex*, *Rendlia altera*, *Setaria nigrirostris*. Herbs: *Berkheya onopordifolia* var. *glabra* (d), *Cephalaria natalensis* (d), *Pelargonium luridum* (d), *Acalypha depressinerva*, *A. peduncularis*, *A. wilmsii*, *Aster bakerianus*, *Berkheya setifera*, *Euryops transvaalensis* subsp. *setilobus*, *Galium thunbergianum* var. *thunbergianum*, *Geranium ornithopodioides*, *Helichrysum cephaloideum*, *H. cooperi*, *H. monticola*, *H. nudifolium* var. *nudifolium*, *H. oreophilum*, *H. simillimum*, *Pentanisia prunelloides* subsp. *latifolia*, *Plectranthus laxiflorus*, *Sebaea leiostyla*, *S. sedoides* var. *sedoides*, *Selago densiflora*, *Vernonia hirsuta*, *V. natalensis*, *Wahlenbergia cuspidata*. Geophytic Herbs: *Hypoxis costata* (d), *Agapanthus inapertus* subsp. *intermedius*, *Asclepias aurea*, *Cheilanthes hirta*, *Corycium dracomontanum*, *C. nigrescens*, *Cyrtanthus tuckii* var. *transvaalensis*, *Disa versicolor*, *Eriospermum cooperi* var. *cooperi*, *Eucomis bicolor*, *Geum capense*, *Gladiolus ecklonii*, *G. sericeovillosus* subsp. *sericeovillosus*, *Hesperantha coccinea*, *Hypoxis rigidula* var. *pilosissima*, *Moraea brevistyla*, *Rhodohypoxis baurii* var. *confecta*. Semiparasitic Herb: *Striga bilabiata* subsp. *bilabiata*.

Biogeographically Important Taxa ([L]Low Escarpment endemic, [N]Northern sourveld endemic) Low Shrubs: *Bowkeria citrina*[L], *Lotononis amajubica*[L], *Protea parvula*[N]. Succulent Herb: *Aloe modesta*[N].

Endemic Taxa Herbs: *Helichrysum aureum* var. *argenteum*, *Selago longicalyx*. Geophytic Herbs: *Kniphofia* sp. nov. ('*laxiflora* Form C'), *Nerine platypetala*. Woody Climber: *Asparagus fractiflexus*.

Conservation Least threatened. Conservation target 27%, less than 1% is statutorily protected in the Paardeplaats Nature Reserve. There are 10 South African Natural Heritage Sites in this unit, although very little of it is formally protected. Land use pressures from agriculture are low (5% cultivated) probably owing to the colder climate and shallower soils. The area is also suited to afforestation, with more than 1% under *Acacia mearnsii* and *Eucalyptus* plantations. The black wattle (*Acacia mearnsii*) is an aggressive invader of riparian areas. Erosion very low (78%) and low (19%).

M.C. Lötter

Figure 8.49 Gm 14 Wakkerstroom Montane Grassland: Frost-tolerant grasslands of the Wakkerstroom area (Mpumalanga) with herbs *Senecio scitus* and *Helichrysum nudifolium* and dominated by the grass *Themeda triandra*.

Remarks This unit represents the northernmost distribution limit for many plant taxa that occur on the Drakensberg Escarpment (e.g. *Helichrysum hypoleucum* and *Protea subvestita*) to the south, as well as the southernmost limit for plants occurring on the Northern Escarpment (e.g. *Protea parvula*). It also contains many of its own endemics and is under investigation as a possible centre of endemism. The higher rainfall and more temperate climate on a somewhat raised escarpment have possibly been conducive to the evolution of local endemics. Unlike its adjacent units, the

Wakkerstroom Montane Grassland is largely devoid of *Pteridium aquilinum*.

References Acocks (1953, 1988), Codd (1968), Eckhardt et al. (1997).

Gm 15 Paulpietersburg Moist Grassland

VT 64 Northern Tall Grassveld (Transition between Piet Retief Sourveld and Southern Tall Grassveld) (60%) (Acocks 1953). LR 43 North-eastern Mountain Grassland (86%) (Low & Rebelo 1996). BRG 11 Moist Transitional Tall Grassveld (53%) (Camp 1999a).

Distribution KwaZulu-Natal and Mpumalanga Provinces: Broad surrounds of Piet Retief, Paulpietersburg and Vryheid, extending westwards to east of Wakkerstroom. Occurs in the uppermost catchments of the Phongolo River. Altitude 920–1 500 m.

A. Lindström

Figure 8.50 Gm 15 Paulpietersburg Moist Grassland: Short grassland along the old Piet Retief–Wakkerstroom road (northern KwaZulu-Natal) interrupted by drainage lines supporting shrublands with *Leucosidea sericea*.

Vegetation & Landscape Features Mainly undulating with moderately steep slopes, but valley basins are wide and flat and mountainous areas occur mostly along the northern and eastern boundary. Tall closed grassland rich in forbs and dominated by *Tristachya leucothrix*, *Themeda triandra* and *Hyparrhenia hirta*. Evergreen woody vegetation is characteristic on rocky outcrops.

Geology & Soils This area is underlain by Archaean granite and gneiss partly covered by Karoo Supergroup sediments (Madzaringwe Formation) and intruded by Karoo Dolerite Suite dykes and sills. Dominant soils on the sedimentary parent material are yellow apedal, well drained, with a depth of >800 mm and a clay content of >35%, representing the soil series: Hutton, Clovelly and Griffin. Shortlands soils are dominant on dolerite. Dominant land type Ac, with Fa and Ba of subordinate importance.

Climate Summer rainfall, with MAP 900 mm. Warm-temperate climate, MAT close to 17°C, with fairly frequent frosts. See also climate diagram for Gm 15 Paulpietersburg Moist Grassland (Figure 8.36).

Important Taxa Graminoids: *Alloteropsis semialata* subsp. *eckloniana* (d), *Andropogon schirensis* (d), *Brachiaria serrata* (d), *Ctenium concinnum* (d), *Cymbopogon caesius* (d), *Digitaria tricholaenoides* (d), *Eragrostis racemosa* (d), *Harpochloa falx* (d), *Heteropogon contortus* (d), *Hyparrhenia hirta* (d), *Loudetia simplex* (d), *Microchloa caffra* (d), *Monocymbium ceresiiforme* (d), *Rendlia altera* (d), *Setaria nigrirostris* (d), *Themeda triandra* (d), *Tristachya leucothrix* (d), *Andropogon appendiculatus*, *Cynodon hirsutus*, *Diheteropogon amplectens*, *D. filifolius*, *Elionurus muticus*, *Eragrostis chloromelas*, *E. curvula*, *E. plana*, *Festuca scabra*, *Melinis nerviglumis*, *Panicum ecklonii*, *P. natalense*, *Trachypogon spicatus*, *Urelytrum agropyroides*. Herbs: *Argyrolobium speciosum* (d), *Cissus diversilobata* (d), *Dicoma zeyheri* (d), *Eriosema kraussianum* (d), *Geranium wakkerstroomianum* (d), *Helichrysum nudifolium* var. *nudifolium* (d), *Ipomoea oblongata* (d), *Pelargonium luridum* (d), *Acalypha glandulifolia*, *A. peduncularis*, *Acanthospermum australe*, *Aster bakerianus*, *Becium filamentosum*, *Berkheya setifera*, *Dicoma anomala*, *Euryops laxus*, *E. transvaalensis* subsp. *setilobus*, *E. transvaalensis* subsp. *transvaalensis*, *Helichrysum rugulosum*, *H. simillimum*, *Indigofera hilaris* var. *hilaris*, *I. velutina*, *Kohautia amatymbica*, *Pearsonia grandifolia*, *Pentanisia prunelloides* subsp. *latifolia*, *Senecio bupleuroides*, *S. coronatus*, *S. inornatus*, *S. isatideus*, *S. latifolius*, *Sonchus nanus*, *Thunbergia atriplicifolia*, *Vernonia capensis*, *V. natalensis*, *Xerophyta retinervis*. Herbaceous Climber: *Rhynchosia totta*. Geophytic Herbs: *Chlorophytum haygarthii* (d), *Gladiolus aurantiacus* (d), *Agapanthus inapertus* subsp. *intermedius*, *Asclepias aurea*, *Cheilanthes hirta*, *Cyrtanthus tuckii* var. *transvaalensis*, *Hypoxis colchicifolia*, *H. costata*, *H. rigidula* var. *pilosissima*, *Moraea brevistyla*, *Pteridium aquilinum*, *Watsonia latifolia*, *Zantedeschia rehmannii*. Succulent Herbs: *Aloe ecklonis*, *A. maculata*, *Lopholaena segmentata*. Small Trees: *Canthium ciliatum* (d), *Dombeya rotundifolia*, *Vangueria infausta*. Succulent Tree: *Aloe marlothii* subsp. *marlothii*. Tall Shrubs: *Calpurnia sericea* (d), *Rhus rehmanniana* (d), *Diospyros lycioides* subsp. *guerkei*, *Euclea crispa* subsp. *crispa*. Low Shrubs: *Rhus discolor* (d), *Anthospermum rigidum* subsp. *pumilum*, *A. rigidum* subsp. *rigidum*, *Clutia monticola*, *Diospyros galpinii*, *Erica oatesii*, *E. woodii*, *Hermannia geniculata*, *Indigofera arrecta*, *Otholobium wilmsii*, *Polygala uncinata*, *Pseudarthria hookeri*, *Rubus rigidus*. Succulent Shrub: *Euphorbia pulvinata*.

Biogeographically Important Taxa (all Low Escarpment endemics) Succulent Herb: *Aloe modesta*. Low Shrubs: *Bowkeria citrina*, *Hemizygia macrophylla*, *Lotononis amajubica*.

Endemic Taxon Succulent Shrub: *Aloe reitzii* var. *vernalis*.

Conservation Vulnerable. Target 24%. Only very small portion statutorily conserved in Witbad, Vryheid Mountain, Paardeplaats and Phongola Bush Nature Reserves. Some private reserves protect small patches (Rooikraal, Mhlongamvula, Kombewaria). About one third already transformed by plantations or cultivated land. Heavy livestock grazing and altered fire regimes have greatly reduced the area of grasslands of high conservation value. Aliens such as species of *Acacia*, *Eucalyptus* and *Pinus* are of major concern in places. Erosion very low (80%) or low (13%).

References Acocks (1953, 1988), Eckhardt et al. (1996a, c), Eckhardt (1998), Camp (1999a).

Gm 16 KaNgwane Montane Grassland

VT 63 Piet Retief Sourveld (57%) (Acocks 1953). LR 43 North-eastern Mountain Grassland (98%) (Low & Rebelo 1996).

Distribution Mpumalanga and Swaziland, and marginally into northern KwaZulu-Natal: Occurs along the gentle slopes of the

J.C. Manning

Figure 8.51 Gm 16 KaNgwane Montane Grassland: Lush mesophilous grassland with rich post-fire display of herbs (*Gerbera viridifolia, Chascanum latifolium*) near Piet Retief (Mpumalanga).

Escarpment, from the Phongolo Valley in the south, northwards to the Usutu Valley and to the uppermost Lomati Valley near Carolina, including the western grassland areas of Swaziland. Altitude 880–1 740 m.

Vegetation & Landscape Features Largely comprised of undulating hills and plains that occur on the eastern edge of the Escarpment. This unit is transitional between the Highveld and Escarpment and contains elements of both. The vegetation structure is comprised of a short closed grassland layer with many forbs, and a few scattered shrubs on the rocky outcrops.

Geology & Soils Mostly on granite of the Mpuluzi Granite (Randian Erathem), Archaean gneiss giving rise to melanic soils, with intrusions of diabase. Land types Ac, Fa and Ba.

Climate Early summer rainfall, with MAP 910 mm, ranging between 800 and 1 250 mm. This unit has a wide range of frost frequency (3–20 days per year), with most frost days occurring in the western regions. See also climate diagram for Gm 16 KaNgwane Montane Grassland (Figure 8.36).

Important Taxa Graminoids: *Alloteropsis semialata* subsp. *eckloniana* (d), *Brachiaria serrata* (d), *Cyperus obtusiflorus* (d), *Diheteropogon amplectens* (d), *D. filifolius* (d), *Eragrostis racemosa* (d), *Heteropogon contortus* (d), *Hyparrhenia hirta* (d), *Loudetia simplex* (d), *Monocymbium ceresiiforme* (d), *Rendlia altera* (d), *Themeda triandra* (d), *Trachypogon spicatus* (d), *Tristachya leucothrix* (d), *Andropogon schirensis*, *Bewsia biflora*, *Bulbostylis burchellii*, *Ctenium concinnum*, *Cymbopogon caesius*, *Cyperus obtusiflorus* var. *obtusiflorus*, *Digitaria diagonalis*, *D. tricholaenoides*, *Eragrostis chloromelas*, *E. plana*, *Eulalia villosa*, *Panicum ecklonii*, *P. natalense*, *Paspalum scrobiculatum*, *Schizachyrium sanguineum*, *Setaria nigrirostris*, *S. sphacelata*. Herbs: *Ipomoea oblongata* (d), *Acalypha peduncularis*, *A. villicaulis*, *Alepidea setifera*, *Argyrolobium speciosum*, *Aster harveyanus*, *Berkheya setifera*, *Corchorus confusus*, *Cyathula cylindrica*, *Dicoma zeyheri*, *Dimorphotheca jucunda*, *Eriosema cordatum*, *Euryops laxus*, *E. transvaalensis* subsp. *setilobus*, *Helichrysum adenocarpum*, *H. cephaloideum*, *H. nudifolium* var. *nudifolium*, *Mohria caffrorum*, *Pentanisia angustifolia*, *P. prunelloides* subsp. *latifolia*, *Ruellia patula*, *Schistostephium crataegifolium*, *Senecio panduriformis*, *Sonchus wilmsii*, *Thunbergia atriplicifolia*, *Vernonia natalensis*, *V. oligocephala*. Geophytic Herbs: *Agapanthus inapertus* subsp. *inapertus*, *Boophone disticha*, *Cheilanthes deltoidea*, *C. hirta*, *Eucomis montana*, *Gladiolus ecklonii*, *Habenaria dregeana*, *Hypoxis iridifolia*, *H. rigidula* var. *pilosissima*, *Moraea pubiflora*, *Pteridium aquilinum*, *Watsonia latifolia*, *Zantedeschia albomaculata* subsp. *macrocarpa*. Succulent Herbs: *Aloe integra*, *A. kniphofioides*. Small Trees: *Acacia caffra*, *Faurea rochetiana*, *Pachystigma macrocalyx*. Tree Fern: *Cyathea dregei*. Tall Shrubs: *Calpurnia glabrata*, *Cephalanthus natalensis*, *Diospyros lycioides* subsp. *guerkei*, *Vernonia tigna*. Low Shrubs: *Heteromorpha involucrata* (d), *Anthospermum rigidum* subsp. *rigidum*, *Asparagus cooperi*, *A. virgatus*, *Athrixia phylicoides*, *Diospyros scabrida* var. *cordata*, *Gymnosporia heterophylla*, *Indigofera comosa*, *Myrsine africana*, *Rhus discolor*, *Schistostephium rotundifolium*.

Biogeographically Important Taxa ([BC]Barberton endemic, [N]Northern sourveld endemic) Herbs: *Hemizygia modesta*[BC], *H. thorncroftii*[BC], *Selago stewartii*[BC]. Geophytic Herb: *Watsonia watsonioides*[N]. Succulent Herb: *Kleinia galpinii*[N]. Low Shrub: *Hemizygia albiflora*[N].

Endemic Taxa Herbs: *Lotononis difformis*, *L. spicata*, *Streptocarpus occultis*. Low Shrub: *Syncolostemon comptonii*.

Conservation Vulnerable. The conservation target 27% with only 0.4% protected within any formally proclaimed nature reserves (Malalotja, Nooitgedacht Dam and Songimvelo). A number of private conservation areas protect small patches of this unit. It is well suited for afforestation and 30% has already been converted to plantations of alien trees. A further 6% is under cultivation. Erosion potential very low (55%) and low (7%).

Remark This area occurs on the southern edge of the Barberton Centre of Endemism.

References Acocks (1953, 1988), De Frey (1999), Van Wyk & Smith (2001).

Gm 17 Barberton Montane Grassland

VT 9 Lowveld Sour Bushveld (41%), VT 8 North-Eastern Mountain Sourveld (34%) (Acocks 1953). LR 21 Sour Lowveld Bushveld (54%) (Low & Rebelo 1996).

Distribution Mpumalanga Province and northwestern Swaziland: From Barberton westwards towards Nelshoogte, northwards along the high-lying grassland areas towards Kaapmuiden and Malelane, and southeast towards Piggs Peak. It generally occurs at high altitudes in the Barberton region, ranging from 760 m in the north to 1 640 m in the southwest.

Vegetation & Landscape Features This unit occurs along the high mountains above Barberton, which rise above the surrounding Lowveld. The terrain is steep, rugged and accessibility is limited. The dominant vegetation is short rocky grassland and gradually becomes woodland along the lower slopes.

Geology & Soils Barberton Supergroup schists, gneiss, felspathic quartzites and various lavas of the Figtree, Moodies, and Onverwacht Formations. Land types Fa (60%) and Ac (20%).

Climate Early summer rainfall, concentrated between November and March. MAP varies between 950 mm in the

west, to 1 470 mm in the east (overall MAP 1 194 mm). Frosts are very infrequent during winter (3 days per year) and increase towards the west (10 days). Hot dry winds occur from August to October. See also climate diagram for Gm 17 Barberton Montane Grassland (Figure 8.36).

Important Taxa Small Trees: *Faurea galpinii*, *F. rochetiana*, *F. saligna*, *Rapanea melanophloeos*. Tree Fern: *Cyathea dregei*. Tall Shrubs: *Cephalanthus natalensis* (d), *Euryops brevipapposus, Gerrardina foliosa*, *Protea gaguedi*. Low Shrubs: *Phymaspermum athanasioides* (d), *Clutia pulchella*, *Erica cerinthoides*, *E. drakensbergensis*, *E. woodii*, *Helichrysum odoratissimum*, *Heteromorpha involucrata*, *Leucospermum gerrardii*, *Protea simplex*, *Psoralea glabra, Schistostephium rotundifolium, Siphonoglossa linifolia*. Succulent Shrub: *Aloe vryheidensis*. Graminoids: *Alloteropsis semialata* subsp. *ecklo-niana* (d), *Andropogon schirensis* (d), *Ctenium concinnum* (d), *Eragrostis racemosa* (d), *Eulalia villosa* (d), *Loudetia simplex* (d), *Monocymbium ceresiiforme* (d), *Rendlia altera* (d), *Themeda triandra* (d), *Brachiaria serrata*, *Brachypodium flexum*, *Digitaria monodactyla*, *Diheteropogon amplectens*, *Hyparrhenia hirta*, *Ischyrolepis schoenoides*, *Melinis nerviglumis*, *Panicum ecklonii*, *P. natalense*, *Pentaschistis natalensis*, *Setaria nigrirostris*, *Trachypogon spicatus*, *Tristachya leucothrix*. Herbs: *Acalypha caperonioides*, *A. glandulifolia*, *Euryops laxus, Helichrysum adenocarpum*, *H. nudifolium* var. *oxyphyllum*, *H. pallidum*, *Selago procera*, *Xerophyta retinervis*. Geophytic Herbs: *Agapanthus inapertus* subsp. *intermedius*, *Cheilanthes hirta*, *Eucomis montana*, *Haemanthus montanus*, *Ledebouria sandersonii*, *Merwilla natalensis*, *Satyrium cristatum*.

Biogeographically Important Taxa ([BC]Barberton endemic, [N]Northern sourveld endemic, [P]Pondoland link) Small Trees: *Encephalartos paucidentatus*[N], *Faurea galpinii*[N], *Protea comptonii*[N]. Tall Shrub: *Tricalysia capensis* var. *galpinii*[N]. Low Shrubs: *Asparagus rigidus*[N], *Helichrysum milleri*[N], *H. mimetes*[N], *H. reflexum*[N], *Hemizygia parvifolia*[N], *Heteromorpha pubescens*[N], *Kotschya parvifolia*[N], *Melhania randii*[N], *Protea parvula*[N], *Syncolostemon eriocephalus*[N]. Succulent Shrubs: *Aloe chortolirioides* var. *chortolirioides*[N], *A. suprafoliata*[N]. Herbs: *Senecio rhyncholaenus*[P] (d), *Hemizygia foliosa*[N], *H. modesta*[BC], *H. thorncrofti*[BC], *H. transvaalensis*[N], *Inezia integrifolia*[N], *Monsonia transvaalensis*[N], *Pearsonia aristata*[N], *Phymaspermum argenteum*[N], *Selago stewartii*[BC], *S. villosa*[N], *Streptocarpus galpinii*[N], *Thorncroftia longiflora*[N]. Geophytic Herbs: *Agapanthus inapertus* subsp. *hollandii*[N], *Aspidonepsis shebae*[N], *Cyrtanthus thorncroftii*[N], *Gladiolus varius*[N], *Watsonia occulta*[N], *W. watsonioides*[N]. Succulent Herbs: *Aloe craibii*, *Kleinia galpinii*[N].

Endemic Taxa Small Trees: *Encephalartos heenanii*, *Protea caffra* subsp. *falcata*, *P. roupelliae* subsp. *hamiltonii*. Tall Shrub: *Tinnea barbata*. Herbs: *Euryops discoideus, Helichrysum calocephalum*, *Hemizygia stalmansii*, *Holothrix culveri*, *Streptocarpus pogonites*, *Thorncroftia thorncroftii*. Geophytic Herb: *Disa intermedia*. Succulent Herb: *Aloe albida*.

Conservation Vulnerable. The conservation target of 27% has almost been reached as 26% of this unit is protected within nature reserves (Songimvelo Game Reserve and Mountainlands Nature Reserve). Almost 40% has been transformed by plantations. Erosion potential very low (75%) and low (9%).

Remarks This vegetation unit occurs within the Barberton Centre of Plant Endemism and the endemics are predominantly comprised of herbaceous plants on a dystrophic substrate. Pockets of forests occur in fire-protected areas.

References Acocks (1953, 1988), Stalmans et al. (1999), Van Wyk & Smith (2001).

Gm 18 Lydenburg Montane Grassland

VT 57 North-Eastern Sandy Highveld (53%) (Acocks 1953). LR 43 North-eastern Mountain Grassland (73%) (Low & Rebelo 1996).

Distribution Mpumalanga Province: From just above Pilgrim's Rest in the north, southwards and westwards skirting Lydenburg, extending to Dullstroom, to Belfast and Waterval Boven in the south. It includes both the Steenkampsberg and Mauchsberg. Altitude 1 260–2 160 m.

Vegetation & Landscape Features High-altitude plateaus, undulating plains, mountain peaks and slopes, hills and deep valleys of the Northern Escarpment region, supporting predominantly very low grasslands on the high-lying areas. Height of the grass sward increases on the lower slopes. The grassland is very rich in forb species.

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Figure 8.52 Gm 17 Barberton Montane Grassland: A mosaic of short grassland and rocky shrubland with *Burchellia bubalina, Helichrysum reflexum, Psychotria capensis* and *Aloe albida* on the Saddleback Mountain, southeast of Barberton (Mpumalanga).

Geology & Soils The soils are mostly derived from shale and quartzite as well as lavas and dolomites of the Pretoria Group of the Transvaal Supergroup (Vaalian Erathem). Land types Ac and Fa cover areas of approximately equal size.

Climate Orographic precipitation and mists throughout most months of the year support a unique flora, including rich mesophytic plants such as the Orchidaceae. MAP 858 mm (660–1 180 mm), augmented by the frequent mists. Frost days 21 days per year, varying greatly between 3 and 40, generally more frost to the west. See also climate diagram for Gm 18 Lydenburg Montane Grassland (Figure 8.36).

Important Taxa Small Trees: *Protea roupelliae* subsp. *roupelliae* (d), *Faurea*

galpinii. Low Shrubs: *Phymaspermum acerosum* (d), *Anthospermum rigidum* subsp. *rigidum*, *Cliffortia repens*, *Erica cerinthoides*, *E. woodii*, *Felicia filifolia* subsp. *filifolia*, *Gnidia caffra*, *Helichrysum odoratissimum*, *H. swynnertonii*, *Heteromorpha involucrata*, *Polygala uncinata*, *Tenrhynea phylicifolia*. Succulent Shrubs: *Lopholaena disticha* (d), *Delosperma lydenburgense*. Graminoids: *Andropogon schirensis* (d), *Aristida junciformis* subsp. *galpinii* (d), *Brachiaria serrata* (d), *Digitaria monodactyla* (d), *D. tricholaenoides* (d), *Diheteropogon filifolius* (d), *Harpochloa falx* (d), *Heteropogon contortus* (d), *Hyparrhenia hirta* (d), *Loudetia simplex* (d), *Monocymbium ceresiiforme* (d), *Setaria nigrirostris* (d), *Sporobolus centrifugus* (d), *Themeda triandra* (d), *Trachypogon spicatus* (d), *Tristachya leucothrix* (d), *Alloteropsis semialata* subsp. *eckloniana*, *Aristida sciurus*, *Bulbostylis oritrephes*, *Ctenium concinnum*, *Cymbopogon caesius*, *Diheteropogon amplectens*, *Elionurus muticus*, *Eragrostis capensis*, *E. chloromelas*, *E. curvula*, *E. gummiflua*, *E. plana*, *E. racemosa*, *E. scleranthe*, *Eulalia villosa*, *Ischyrolepis schoenoides*, *Koeleria capensis*, *Microchloa caffra*, *Panicum ecklonii*, *P. natalense*, *Pentaschistis natalensis*, *Rendlia altera*, *Schizachyrium sanguineum*, *Sporobolus pectinatus*, *Tristachya rehmannii*. Herbs: *Senecio gerrardii* (d), *Acalypha angustata*, *A. depressinerva*, *Alepidea longifolia*, *Dicoma anomala*, *Dimorphotheca jucunda*, *D. spectabilis*, *Eriosema kraussianum*, *Gerbera ambigua*, *Haplocarpha scaposa*, *Helichrysum caespititium*, *H. chionosphaerum*, *H. nudifolium H. rugulosum*, *H. spiralepis*, *H. subglomeratum*, *H. umbraculigerum*, *Monopsis decipiens*, *Myosotis afropalustris*, *Pelargonium luridum*, *Pentanisia prunelloides* subsp. *latifolia*, *Polygala amatymbica*, *Psammotropha myriantha*, *Rhynchosia monophylla*, *Schistostephium crataegifolium*, *Sebaea erosa*, *S. sedoides* var. *confertiflora*, *Selago procera*, *Senecio laevigatus*, *Vernonia hirsuta, V. natalensis*, *V. oligocephala*, *Wahlenbergia undulata*, *Zornia capensis*. Herbaceous Climber: *Rhynchosia totta*. Geophytic Herbs: *Gladiolus longicollis* subsp. *platypetalus* (d), *Agapanthus inapertus* subsp. *inapertus*, *A. inapertus* subsp. *intermedius*, *Chlorophytum haygarthii*, *Corycium dracomontanum*, *C. nigrescens*, *Disa fragrans* subsp. *fragrans*, *D. versicolor*, *Disperis renibractea*, *Gladiolus ecklonii*, *Habenaria dives*, *H. dregeana*, *H. lithophila*, *Haemanthus humilis* subsp. *hirsutus*, *Holothrix scopularia*, *Hypoxis costata*, *H. galpinii*, *H. rigidula* var. *pilosissima*, *Merwilla natalensis*, *Pachycarpus transvaalensis*, *Raphionacme galpinii*, *Satyrium longicauda*, *Zantedeschia albomaculata* subsp. *macrocarpa*. Succulent Herbs: *Aloe dyeri*, *A. graciliflora, A. longibracteata*, *Crassula vaginata*.

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Figure 8.53 Gm 18 Lydenburg Montane Grassland: Short rocky mistbelt grassland with *Rhus tumulicola, Vernonia hirsuta* and species of *Berkheya* and *Helichrysum* at Kemps Heights, 17 km southeast of Lydenburg (Mpumalanga).

Biogeographically Important Taxa (all Northern sourveld endemics) Herbs: *Graderia linearifolia*, *Helichrysum truncatum*, *Hemizygia foliosa*, *Inezia integrifolia*, *Monsonia transvaalensis*, *Selago compacta*, *S. villosa*, *Streptocarpus galpinii*, *Tetraselago wilmsii*. Geophytic Herbs: *Agapanthus inapertus* subsp. *hollandii*, *A. inapertus* subsp. *parviflorus*, *A. inapertus* subsp. *pendulus*, *Gladiolus calcaratus*, *G. exiguus*, *Watsonia occulta*. Succulent Herb: *Aloe affinis*. Low Shrubs: *Helichrysum albilanatum*, *H. mariepscopicum*, *H. milleri*, *H. reflexum*, *H. rudolfii*, *Hemizygia albiflora*, *H. subvelutina*, *Sutera polelensis* subsp. *fraterna*.

Endemic Taxa Low Shrubs: *Erica atherstonei*, *E. holtii*, *Helichrysum lesliei*, *H. summo-montanum*. Succulent Shrub: *Khadia alticola*. Herbs: *Crotalaria monophylla*, *Cymbopappus piliferus*, *Knowltonia transvaalensis* var. *pottiana*, *Pearsonia hirsuta*, *Streptocarpus cyaneus* subsp. *longi-tommii*, *S. hilburtianus*. Geophytic Herbs: *Disa alticola*, *D. amoena*, *D. clavicornis*, *Eucomis vandermerwei*, *Gladiolus cataractarum*, *G. exiguus*, *G. malvinus*, *Kniphofia rigidifolia*, *Riocreuxia aberrans*, *Schizochilus cecilii* subsp. *transvaalensis, S. lilacinus, Watsonia occulta, W. wilmsii*. Succulent Herb: *Crassula setulosa* var. *deminuta*.

Conservation Vulnerable. The conservation target is 27%, with 2.4% formally protected within reserves (Gustav Klingbiel, Makobulaan, Mt Anderson, Ohrigstad Dam, Sterkspruit and Verlorenvlei) as well as in a number of private conservation areas (Buffelskoof, Crane Creek, ETTC, In-de-Diepte, Kaalboom, Kalmoesfontein, Mbesan, Mondi Indigenous Forest, Mt Sheba, Waterval etc.). The level of transformation is relatively high at 23%, with mostly alien plantations (20%) and cultivated lands (2%). Erosion potential very low (74%) and low (12%).

Remark 1 This unit has an afromontane flora with links to the Zimbabwean highlands in the north (e.g. *Morella microbracteata*, *Selago procera*, *Helichrysum swynnertonii*) and the southern Drakensberg in the south (e.g. *Polypodium vulgare*, *Helichrysum spodiophyllum*, *Selago compacta*, *Holothrix scopularia*). It has also been proposed as a centre of plant endemism. Over 2 266 plant taxa have been identified in an area roughly corresponding to that of the Lydenburg Montane Grassland, with a list of 51 endemics. The recognition of two subcentres was also proposed, namely the Long Tom Pass and the Steenkampsberg Subcentres. The flora varies between these two areas, with the Long Tom Pass region having several elements linking it to escarpment flora of the north, while the Steenkampsberg has several elements linking it to the flora in the south, as in Wakkerstroom and southern Drakensberg. Elements linking the Long Tom Pass to the north (Wolkberg and northwards) include *Helichrysum rudolfii*, *H. mariepscopicum*, *Dierama adelphicum*, *Schizochilus cecilii* subsp. *transvaalensis* and *Kniphofia splendida*. The elements linking the Steenkampsberg to the south include *Aloe modesta*, *Helichrysum subglomeratum*, *Brunsvigia natalensis*, *Habenaria tysonii* and *Disperis oxyglossa*. Furthermore, in the Long Tom Pass area, *Psoralea latifolia* and *Lopholaena disticha* are replaced by *Otholobium wilmsii* and *L. segmentata*.

Remark 2 Small forests and shrub-like thickets are common along drainage lines, faults, and narrow diabase dykes (which are common in this unit).

References Acocks (1953, 1988), Deall (1985), Bloem (1988), Deall et al. (1989), Bloem et al. (1993), Burgoyne (1995), Emery et al. (2002).

Gm 19 Sekhukhune Montane Grassland

VT 61 Bankenveld (49%), VT 57 North-Eastern Sandy Highveld (40%) (Acocks 1953). LR 18 Mixed Bushveld (59%) (Low & Rebelo 1996).

Distribution Mpumalanga Province: continuous undulating norite hills in the Roossenekal region, from Stoffberg in the south, northwards through Mapochs Gronde to Schurinksberg in the north, with the Steelpoort River in the west. Altitude 1 300–1 960 m.

Vegetation & Landscape Features Major chains of hills transect the area and have a north-south orientation, creating moderately steep slopes with predominantly eastern and western aspects. Large norite boulders and stones cover the shallow soils on the hillsides. Dense, sour grassland occur on slopes of mountains and undulating hills, with scattered clumps of trees and shrubs in sheltered habitats. Turf and clay soils characterise the open plains between the chains of hills and culminate in a open plain in the Stoffberg area. Dense, tall grassland is found on the plains and encroachment by indigenous or invasion by alien microphyllous tree species is common in places.

Geology & Soils The area mostly overlies the mafic intrusive rocks of the Upper and Main Zones of the Rustenburg Layered Suite, which is economically the most important part of the Bushveld Igneous Complex (Vaalian Erathem). The west of this area is dominated by diorite and gabbro (often magnetite-rich) of the Roossenekal Subsuite, whereas the east is dominated by gabbro and norite of the Dsjate Subsuite. In the extreme north-east of the area are metasediments of the Pretoria Group (also Vaalian Erathem) that were metamorphosed by the intrusion of the Bushveld Igneous Complex. Substrates of the undulating hills are generally heterogeneous rocky areas with miscellaneous soil types and those of the southern plains have diagnostic horizons that are vertic, melanic or red-structured. Dominant soil forms have a high clay content and include Arcadia, Mayo, Milkwood, Mispah, Shortlands and Steendal. Ea land type covers 40% of the area, with minor occurrences of Ib and Ab.

Climate This unit experiences a similar climate to the adjacent Lydenburg Montane Grassland, although frost incidence decreases towards the north. Summer-rainfall regime with the MAP from about 720 mm in the east to 600 mm in the west, much of the rain falling in the form of thunderstorms in summer from November to January. Mean daily temperature ranges from a minimum of 2.8°C in winter to a maximum of 24.9°C in summer. Daily temperatures vary considerably at different localities, with higher temperatures on the plains and lower temperatures on higher-lying plateaus. See also climate diagram for Gm 19 Sekhukhune Montane Grassland (Figure 8.36).

Important Taxa Small Trees: *Protea caffra* subsp. *caffra* (d), *Acacia caffra*, *Apodytes dimidiata* subsp. *dimidiata*, *Canthium suberosum*, *Cussonia transvaalensis*, *Seemannaralia gerrardii*. Woody Climbers: *Rhoicissus tridentata* (d), *Jasminum quinatum*, *Triaspis glaucophylla*. Tall Shrubs: *Euclea crispa* subsp. *crispa* (d), *Brachylaena ilicifolia*, *Diospyros austro-africana*, *Euclea linearis*, *Pavetta zeyheri*. Low Shrubs: *Gnidia caffra* (d), *Senecio microglossus* (d), *Dyschoriste rogersii*, *Elephantorrhiza praetermissa*, *Leonotis leonurus, Polygala uncinata*, *Rhus discolor*, *R. tumulicola* var. *meeuseana*, *R. wilmsii*. Geoxylic Suffrutex: *Elephantorrhiza elephantina*. Graminoids: *Aristida junciformis* subsp. *galpinii* (d), *Diheteropogon amplectens* (d), *Elionurus muticus* (d), *Eragrostis chloromelas* (d), *E. racemosa* (d), *Heteropogon contortus* (d), *Microchloa caffra* (d), *Monocymbium ceresiiforme* (d), *Setaria sphacelata* (d), *Themeda triandra* (d), *Tristachya leucothrix* (d), *Andropogon schirensis*, *Aristida aequiglumis*, *Brachiaria serrata*, *Cymbopogon caesius*, *Digitaria diagonalis*, *D. monodactyla*, *Ehrharta capensis*, *Eragrostis capensis*, *E. nindensis*, *E. plana*, *Hyparrhenia hirta*, *Loudetia simplex*, *Panicum natalense*, *Setaria nigrirostris*, *Trachypogon spicatus*, *Triraphis andropogonoides*. Herbs: *Acalypha punctata* (d), *Berkheya setifera* (d), *Rotheca hirsuta* (d), *Senecio latifolius* (d), *Tephrosia purpurea* subsp. *leptostachya* (d), *Berkheya insignis*, *Gerbera jamesonii*, *Helichrysum nudifolium* var. *nudifolium*, *Ipomoea crassipes*, *Jamesbrittenia silenoides*, *Macledium zeyheri* subsp. *argyrophylum*, *Pegolettia lanceolata*, *Pentanisia prunelloides* subsp. *prunelloides*, *Senecio coronatus*, *Vernonia galpinii*, *V. natalensis*, *V. oligocephala*, *Xerophyta retinervis*. Geophytic Herbs: *Hypoxis rigidula* var. *pilosissima* (d), *Cheilanthes hirta*, *Eucomis montana*, *Hypoxis hemerocallidea*, *Pachycarpus transvaalensis*. Succulent Herb: *Kleinia stapeliiformis*.

Biogeographically Important Taxa ([N]Northern sourveld endemic, [SK]Sekhukhune endemic) Small Trees: *Euclea sekhukhuniensis*[SK], *Lydenburgia cassinoides*[SK], *Rhus sekhukhuniensis*[SK]. Woody Climber: *Rhoicissus sekhukhuniensis*[SK]. Tall Shrub: *Vitex obovata* subsp. *wilmsii*[N]. Low Shrubs: *Dyschoriste perrottetii*[SK], *Grewia vernicosa*[N], *Helichrysum uninervium*[N], *Jamesbrittenia macrantha*[SK], *Melhania randii*[N]. Succulent Shrub: *Aloe castanea*[N], Herbs: *Berkheya densifolia*[N], *Cyanotis pachyrrhiza*[N], *Graderia linearifolia*[N], *Ipomoea bathycolpos* var. *sinuatodentata*[SK], *Rhynchosia rudolfii*[N], *Tetraselago wilmsii*[N]. Geophytic Herbs: *Gladiolus sekukuniensis*[SK], *Zantedeschia pentlandii*[SK]. Succulent Herb: *Huernia insigniflora*[N].

Endemic Taxa Succulent Shrubs: *Aloe reitzii* var. *reitzii*, *Delosperma deilanthoides*. Geophytic Herbs: *Resnova* sp. nov. ('*megaphylla*'), *Zantedeschia pentlandii*.

Conservation Vulnerable. Conservation target 24%. Approximately 30% of this area is under commercial or subsistence cultivation. Vast areas are mined for vanadium using strip mining, and in recent years mining of gabbro has increased substantially (Siebert et al. 2002c). There is no formal conservation in the region, although many farmers have embarked on ecotourism initiatives. Erosion very low (56%), moderate (18%) and high (16%).

Remarks This vegetation comprises the Roossenekal Subcentre of the Sekhukhuneland CE (Van Wyk & Smith 2001) with numerous endemic plant species, many of which are not yet described. The Roossenekal area comprises heterogeneous rocky habitats (Siebert et al. 2003) and numerous floristic links with other grassland areas have been identified. In terms of floristic diversity, species richness and vegetation structure, this vegetation is related to Gm 11 Rand Highveld Grassland, Gm 18 Lydenburg Montane Grassland and Gm 17 Barberton Montane Grassland (Siebert et al. 2002b, Bredenkamp & Brown 2003). A floristic link exists with other mesic mountainous areas in South Africa (Mpumalanga and KwaZulu-Natal) and Swaziland and is supported by the following species: *Dyschoriste rogersii*, *Eucomis montana*, *Jamesbrittenia silenoides*, *Pachycarpus transvaalensis*, *Pegolettia lanceolata*, *Seemannaralia gerrardii* and *Thesium multiramulosum*. Floristic links also exist with the Northern Cape, namely *Amphiglossa triflora* and *Nuxia gracilis*, and the Eastern Cape, namely *Brachylaena ilicifolia* and *Maytenus albata*. Species such as *Euclea linearis* and *Melhania randii* are shared with the Great Dyke in Zimbabwe that is located on similar ultramafic rock (Siebert et al. 2001).

References Acocks (1953, 1988), Siebert (2001), Siebert et al. (2001, 2002a, b, c, 2003), Van Wyk & Smith (2001), Bredenkamp & Brown (2003).

Gm 20 Leolo Summit Sourveld

VT 57 North-Eastern Sandy Highveld (88%) (Acocks 1953). LR 18 Mixed Bushveld (100%) (Low & Rebelo 1996).

Distribution Limpopo Province: Discontinuous summits on the Leolo Mountain range, which forms an extension to the norite massif of the Dwars River Mountains further south. Sekhukhune is the major town in the vicinity and lies on the western foot slopes of the mountain. The unit is restricted to altitudes of 1 700–1 920 m.

Vegetation & Landscape Features Summit plateaus on a major mountain range with steep slopes. Large norite boulders and stones cover the shallow soils on the hillsides and plateau. Dense, sour grassland occurs on the high-altitude upper slopes and summit of the mountain; scattered clumps of trees and shrubs occur in sheltered, rocky habitats on the plateau.

Geology & Soils Underlain by the banded gabbros, norites and anorthosites of the Dsjate Subsuite of the Rustenburg Layered Suite (part of the Vaalian Bushveld Igneous Complex). The Dsjate Subsuite forms part of the Main Zone of the Rustenburg Layered Suite. Substrates of the undulating plateau are soils of especially the Mayo and Oakleaf forms in the flat areas, with miscellaneous rocky soil forms, such as Glenrosa and Mispah, occurring on the mountain slopes. Dominant soil forms have a high clay content. The almost exclusive land type is Fb.

Climate This area experiences a similar climate to the Gm 18 Lydenburg Montane Grassland. MAP 694 mm with about half of the rain falling as thunderstorms in summer from November to January. Mean daily temperatures on the summit are considerably lower than those of the surrounding Steelpoort River Valley. See also climate diagram for Gm 20 Leolo Summit Sourveld (Figure 8.36).

Important Taxa Small Trees: *Cussonia transvaalensis*, *Greyia radlkoferi*, *Maytenus albata*, *Protea caffra* subsp. *caffra*, *P. roupelliae* subsp. *roupelliae*. Tall Shrubs: *Euryops brevipappo-sus* (d), *Vernonia myriantha* (d), *Buddleja auriculata*, *B. saligna*, *Euclea crispa* subsp. *crispa*, *Leucosidea sericea*, *Pavetta zeyheri*. Low Shrubs: *Helichrysum splendidum* (d), *Clutia pulchella*, *Gnidia caffra*, *Polygala uncinata*, *P. virgata*, *Rhus discolor*, *Senecio microglossus*. Succulent Shrub: *Aloe arborescens*. Geoxylic Suffrutex: *Elephantorrhiza elephantina*. Graminoids: *Diheteropogon amplectens* (d), *Elionurus muticus* (d), *Eragrostis capensis* (d), *E. curvula* (d), *Setaria sphacelata* (d), *Themeda triandra* (d), *Tristachya leucothrix* (d), *Brachiaria serrata*, *Hyparrhenia hirta*, *Sporobolus centrifugus*. Herbs: *Hirpicium bechuanense* (d), *Pentanisia prunelloides* subsp. *prunelloides* (d), *Acalypha punctata*, *Anagallis huttonii*, *Berkheya insignis*, *Jamesbrittenia silenoides*, *Lotononis foliosa*, *Manulea parviflora*, *Pegolettia lanceolata*, *Rotheca hirsuta*, *Senecio latifolius*, *Xerophyta viscosa*. Geophytic Herb: *Hypoxis rigidula* var. *pilosissima*.

Biogeographically Important Taxa ([N]Northern sourveld endemic, [SK]Sekhukhune endemic, [Z]Link to Zimbabwe) Tall Shrub: *Vitex obovata* subsp. *wilmsii*[N]. Woody Climber: *Rhoicissus sekhukhuniensis*[SK]. Low Shrubs: *Asparagus sekukuniensis*[SK], *Grewia vernicosa*[N], *Helichrysum rudolfii*[N], *H. uninervium*[N], *Hibiscus barnardii*[SK], *Jamesbrittenia macrantha*[SK], *Melhania randii*[N], *Plectranthus venteri*[Z]. Herbs: *Berkheya densifolia*[N], *Cyanotis pachyrrhiza*[N], *Nemesia zimbabwensis*[Z]. Herbaceous Climber: *Cyphia transvaalensis*[N]. Geophytic Herbs: *Gladiolus sekukuniensis*[SK], *Zantedeschia jucunda*[SK]. Succulent Herb: *Aloe affinis*[N].

Conservation Vulnerable. Target 24%. Although sparsely populated, very little of the Grassland Biome on the Leolo Mountains has remained undisturbed due to extensive subsistence agriculture. Threatened by the mining of granite for dimension stone. Although the moist summit of the Leolo Mountains has important value as a water source to the surrounding arid valleys, it has never been regarded as a conservation priority. Erosion very high (48%) and moderate (45%).

Remark 1 This vegetation comprises the Leolo Subcentre of the Sekhukhuneland CE (Van Wyk & Smith 2001), with several taxa still pending description. Interesting biogeographical patterns have been documented for *Triaspis glaucophylla* (link to the Waterberg), *Limosella maior* (link to the Drakensberg) and *Nemesia zimbabwensis* (link to Mount Inyangani in Zimbabwe; Siebert & Van Wyk 2005).

Remark 2 Leolo Summit Sourveld is a high-altitude variant of Sekhukhune Montane Grassland, with the main difference being its much shorter vegetation structure and poorer floristic diversity (Siebert et al. 2002b). It also shares many species with the high-altitude areas of the Lydenburg Montane Grassland, as both are characterised by wetlands and vast seepage areas rich in organic matter.

References Acocks (1953, 1988), Siebert (2001), Van Wyk & Smith (2001), Siebert et al. (2002a, b, c, 2003), Siebert & Van Wyk (2005).

Gm 21 Lydenburg Thornveld

VT 19 Sourish Mixed Bushveld (28%), VT 8 North-Eastern Mountain Sourveld (22%) (Acocks 1953). LR 43 North-eastern Mountain Grassland (80%) (Low & Rebelo 1996).

M.C. Lötter

Figure 8.54 Gm 21 Lydenburg Thornveld: A late spring view of a thornveld in the Lydenburg surrounds, with *Acacia karroo, Rhus pyroides, Celtis africana, Senecio microglossus, Argyrolobium wilmsii* and *Aloe longibracteata*.

Distribution Mpumalanga Province: Situated in a broad band between the high-lying mountains from just north of Ohrigstad, tapering southwards through Lydenburg to as far south as the area in the vicinity of the Kwena Dam. Altitude 1 160 –1 660 m.

Vegetation & Landscape Features This unit occurs at lower levels at the foot of the mountains and on undulating plains. This is open, frost-hardy woodland. Structurally this unit comprises closed grassland which is almost always wooded, sometimes densely so in rocky areas and less so in frost-ridden valleys where *Acacia karroo* is still able to persist. Many woody plants have evolved a suffrutex habit (*Argyrolobium wilmsii*), where aerial parts die back to an underground rootstock during cold winters.

Geology & Soils Red clay soils mostly derived from shales of the Pretoria Group (including the Silverton and Timeball Hill Formations). Shales occasionally intersected with bands of quartzite or andesite. Land types Ba, Fa, Ib and Ae, with predominantly Mispah, Glenrosa or Hutton soil forms.

Climate This unit occurs in the rainshadow of the Escarpment, where the climate is much drier and the winters are very cold (MAT 16°C). The rainfall is generally lower than in surrounding areas since it falls within a rainshadow. Rainfall 580–810 mm (MAP 707 mm). Most of this unit experiences fairly infrequent frost. See climate diagram for Gm 21 Lydenburg Thornveld (Figure 8.36).

Important Taxa Small Trees: *Acacia robusta* subsp. *robusta* (d), *Cussonia transvaalensis* (d), *Acacia caffra*, *A. karroo*, *Combretum erythrophyllum*, *Cussonia paniculata*, *Dombeya rotundifolia*. Tall Shrubs: *Diospyros lycioides* subsp. *guerkei*, *Euclea crispa* subsp. *crispa*, *Ormocarpum kirkii*, *Rhamnus prinoides*, *Vernonia crataegifolia*. Woody Climbers: *Jasminum quinatum* (d), *Acacia ataxacantha*. Low Shrubs: *Rubus transvaaliensis* (d), *Senecio microglossus* (d), *Anthospermum rigidum* subsp. *pumilum*, *Lippia javanica*, *Nemesia fruticans*, *Polygala nodiflora*, *Rhus gerrardii*. Succulent Shrubs: *Euphorbia clavarioides* var. *truncata*, *Lopholaena coriifolia*. Geoxylic Suffrutex: *Elephantorrhiza elephantina*. Graminoids: *Aristida canescens* (d), *A. congesta* (d), *A. diffusa* (d), *Brachiaria serrata* (d), *Bulbostylis burchellii* (d), *Digitaria tricholaenoides* (d), *Eragrostis racemosa* (d), *Heteropogon contortus* (d), *Microchloa caffra* (d), *Schizachyrium sanguineum* (d), *Trachypogon spicatus* (d), *Tristachya leucothrix* (d), *Andropogon schirensis*, *Bewsia biflora*, *Cymbopogon caesius*, *Diheteropogon amplectens*, *Elionurus muticus*, *Eragrostis chloromelas*, *E. gummiflua*, *E. patentissima*, *E. plana*, *Eulalia villosa*, *Hyparrhenia hirta*, *Melinis repens* subsp. *repens*, *Monocymbium ceresiiforme*, *Panicum natalense*, *Schizachyrium ursulus*, *Setaria nigrirostris*, *S. sphacelata*, *Sporobolus centrifugus*, *S. pyramidalis*, *Themeda triandra*, *Tristachya biseriata*, *T. rehmannii*. Herbs: *Acalypha glandulifolia*, *Dicoma anomala*, *Eriosema kraussianum*, *Geigeria burkei* subsp. *burkei*, *Helichrysum cephaloideum*, *H. rugulosum*, *Kohautia amatymbica*, *Macledium zeyheri* subsp. *argyrophylum*, *Rotheca hirsuta*, *Schistostephium crataegifolium*, *Senecio bupleuroides*, *S. coronatus*, *Vernonia oligocephala*. Geophytic Herbs: *Hypoxis multiceps*, *H. rigidula* var. *pilosissima*. Succulent Herbs: *Aloe fosteri*, *A. greatheadii* var. *davyana*, *Kleinia stapeliiformis*.

Endemic Taxa Low Shrubs: *Argyrolobium wilmsii* (d), *Adenia wilmsii*. Geophytic Herb: *Gladiolus rufomarginatus*.

Conservation Vulnerable. The conservation target is 27% and 2% is protected (Gustav Klingbiel and Ohrigstad Dam Nature Reserves). A total of 22% of this unit has been transformed, mainly by dryland and irrigated cultivation. Rainfall generally too low for plantations. Erosion from very low (45%), low (26%) and moderate (18%).

Remark It is a transition zone between the high-lying grasslands and the warmer and drier bushveld areas.

References Acocks (1953, 1988).

Gm 22 Northern Escarpment Dolomite Grassland

VT 8 North-Eastern Mountain Sourveld (70%) (Acocks 1953). LR 43 North-eastern Mountain Grassland (75%) (Low & Rebelo 1996).

Distribution Mpumalanga Province: From the high-lying dolomite grasslands of the Abel Erasmus Pass and Motlatse (Blyde) River (Vaalhoek) areas in the north, it extends southwards in a broad dolomite band along the Northern Escarpment, to as far south as the vicinity of Kaapsehoop. Altitude 1 000–1 620 m.

Vegetation & Landscape Features Very species-rich grasslands that occur along the Escarpment dolomite belt. The grasslands are characterised by a very diverse shrub layer which varies in height and density. The herbaceous component becomes more dense northwards as the climate becomes drier.

Geology & Soils Malmani dolomites of the Chuniespoort Group (Transvaal Supergroup) which overlies the Black Reef Quartzite Formation. Soils usually have a high pH, are rich in calcium and magnesium, and with low phosphorus status.

M. Stalmans

Figure 8.55 Gm 22 Northern Escarpment Dolomite Grassland: Rocky dolomite grassland on the Farm Dientjie (Blyde River Canyon National Park, Mpumalanga) with the grass *Loudetia simplex* and scattered woody species such as *Cussonia paniculata, Protea caffra, Ziziphus mucronata* and *Smilax kraussiana*.

Deep Hutton and Griffin soil forms are common. Land types Fa, Ab and Ac.

Climate Summer rainfall, varying from 700 mm in the north, increasing southwards to 1 420 mm (MAP 1 034 mm). Most of this unit occurs in the mistbelt, with increased precipitation. Warm-temperate climate, with low frequency of frost. Temperature increases northwards, ranging from MAT of 15°C in the south to 17°C in the northern regions of the unit. See also climate diagram for Gm 22 Northern Escarpment Dolomite Grassland (Figure 8.36).

Important Taxa Small Trees: *Seemannaralia gerrardii* (d), *Cussonia natalensis*, *Faurea rochetiana*, *F. saligna*, *Hippobromus pauciflorus*, *Ozoroa albicans*, *Protea caffra* subsp. *caffra*, *P. roupelliae* subsp. *roupelliae*. Tall Shrubs: *Pavetta lanceolata* (d), *Diospyros lycioides* subsp. *sericea*, *Protea gaguedi*, *Rhus rehmanniana*, *Tarchonanthus parvicapitulatus*. Low Shrubs: *Argyrolobium transvaalense*, *Athrixia arachnoidea*, *Chaetacanthus burchellii*, *Erica drakensbergensis*, *Helichrysum splendidum*, *Pelargonium dolomiticum*, *Phymaspermum acerosum*, *Rhus tumulicola* var. *meeuseana*, *Schistostephium rotundifolium*, *Stoebe plumosa*, *Tenrhynea phylicifolia*. Graminoids: *Cymbopogon caesius* (d), *C. nardus* (d), *Elionurus muticus* (d), *Eragrostis capensis* (d), *Hyparrhenia filipendula* (d), *Loudetia simplex* (d), *Monocymbium ceresiiforme* (d), *Schizachyrium sanguineum* (d), *Trichopteryx dregeana* (d), *Tristachya leucothrix* (d), *Alloteropsis semialata* subsp. *eckloniana*, *Andropogon schirensis*, *Digitaria maitlandii*, *Diheteropogon filifolius*, *Eragrostis plana*, *E. racemosa*, *Festuca costata*, *Melinis nerviglumis*, *M. repens* subsp. *repens*, *Rendlia altera*, *Sporobolus africanus*, *S. pectinatus*, *Stiburus alopecuroides*, *Themeda triandra*. Herbs: *Hypodematium crenatum* (d), *Barleria ovata*, *Conostomium natalense*, *Dicoma anomala*, *Helichrysum miconiifolium*, *H. thapsus*, *Pearsonia sessilifolia* subsp. *marginata*, *P. sessilifolia* subsp. *sessilifolia*, *Rhynchosia monophylla*, *Senecio panduriformis*, *Vernonia natalensis*, *Xerophyta retinervis*. Geophytic Herbs: *Cheilanthes pentagona* (d), *Pteris vittata* (d). Succulent Herbs: *Aloe fouriei*, *Crassula sarcocaulis*.

Biogeographically Important Taxa ([N]Northern sourveld endemic, [W]Wolkberg endemic) Low Shrubs: *Berkheya pauciflora*[W], *Heteromorpha pubescens*[N]. Herbs: *Hemizygia transvaalensis*[N] (d), *Phymaspermum argenteum*[N], *Scabiosa transvaalensis*[W].

Endemic Taxa Small Tree: *Ozoroa* sp. nov. ('*laetans*'). Low Shrubs: *Salvia dolomitica* (d), *Pelargonium album*. Succulent Shrub: *Aloe alooides*. Semiparasitic Shrub: *Thesium davidsonae*. Geophytic Herbs: *Gladiolus macneilii, G. pavonia*, *Ledebouria parvifolia*.

Conservation Endangered. Target 27%. Only 2% protected within the Blyde River Canyon National Park, but larger portion protected in private Driekop Caves and London heritage sites in the north and in the Mooifontein and Mondi Cycad Reserve heritage sites in the south. More than half of this unit has been transformed (52%), mainly by plantations (47%) and cultivated lands (5%). Erosion potential very low (17%), low (51%) and moderate (28%).

Remarks Large variation in altitude and rainfall results in differences in species composition. These dolomites support species usually associated with the Wolkberg Centre of Plant Endemism, although some species are also shared with the Sekhukhune Centre of Plant Endemism (e.g. *Dombeya autumnalis*).

References Acocks (1988), Matthews (1991), Matthews et al. (1992a, b, 1993, 1994), Siebert (2001), Van Wyk & Smith (2001).

Gm 23 Northern Escarpment Quartzite Sourveld

VT 8 North-Eastern Mountain Sourveld (72%) (Acocks 1953). LR 21 Sour Lowveld Bushveld (53%) (Low & Rebelo 1996).

Distribution Limpopo and Mpumalanga Provinces: Occurring along the high-altitude crests of the Northern Escarpment, from Haenertsburg in the north, southeastwards, then bending southwards past Blyde River Canyon, Graskop and as far south as the vicinity of Kaapsehoop. Altitude 1 000–1 740 m.

Vegetation & Landscape Features The landscape is characteristically very rugged, with steep east-facing cliffs. This escarpment is intersected in some areas with large east-flowing rivers. Short, closed grassland rich in forb species with scattered trees and shrubs. This unit is very rocky and occurs on weather-resistant quartzite. The nutrient-poor soils lead to a lower biomass which, together with the rocky landscape, results in a reduced frequency and intensity of fires. It therefore has slightly more woody elements than the adjacent units.

Geology & Soils Black Reef Group and Wolkberg Group quartzite (formed 2.5 gya and occurring at the base of the Transvaal Supergroup), covered with shallow rocky soils of the Mispah form. Dominant land type Ab, with Ib, Fa and Ac of subordinate importance.

Climate Summer rainfall, but orographic effects enhance precipitation (overall regional MAP 1 176 mm). Mist common along the highest areas. Warm-temperate climate (MAT 16.6°C), with infrequent frost. See also climate diagram for Gm 23 Northern Escarpment Quartzite Sourveld (Figure 8.36).

M.C. Lötter

Figure 8.56 Gm 23 Northern Escarpment Quartzite Sourveld: Complex of short grassland with scattered woody vegetation (*Protea roupelliae, P. rubropilosa, Schefflera umbellifera* and *Erica caffrorum*) occurring on quartzitic outcrops of the Wolkberg summit on the eastern escarpment.

Important Taxa Small Trees: *Protea roupelliae* subsp. *roupelliae* (d), *Faurea galpinii*, *F. rochetiana*, *Syzygium cordatum* var. *cordatum*. Tree Fern: *Cyathea dregei*. Tall Shrub: *Vernonia myriantha*. Low Shrubs: *Athrixia phylicoides*, *Clutia monticola*, *Crotalaria doidgeae*, *Erica woodii*, *Euryops pedunculatus*, *Helichrysum kraussii*, *H. obductum*, *H. wilmsii*, *Phymaspermum acerosum*, *P. bolusii*, *Rhus tumulicola* var. *meeuseana*. Succulent Shrubs: *Lopholaena coriifolia* (d), *Aloe arborescens*, *Crassula sarcocaulis*. Graminoids: *Aristida junciformis* subsp. *galpinii* (d), *Loudetia simplex* (d), *Melinis nerviglumis* (d), *Monocymbium ceresiiforme* (d), *Panicum ecklonii* (d), *Trachypogon spicatus* (d), *Tristachya leucothrix* (d), *Alloteropsis semialata* subsp. *eckloniana*, *Andropogon appendiculatus*, *Cymbopogon nardus*, *Digitaria maitlandii*, *Diheteropogon filifolius*, *Elionurus muticus*, *Festuca costata*, *Hyparrhenia poecilotricha*, *Ischyrolepis schoenoides*, *Juncus lomatophyllus*, *Koeleria capensis*, *Merxmuellera drakensbergensis*, *Microchloa caffra*, *Pentaschistis natalensis*, *Rendlia altera*, *Schizachyrium sanguineum*, *Sporobolus pectinatus*, *Stiburus alopecuroides*, *Themeda triandra*, *Trichopteryx dregeana*. Herbs: *Rhynchosia woodii* (d), *Acalypha glandulifolia*, *Anisopappus smutsii*, *Aster harveyanus*, *Berkheya echinacea*, *Craterocapsa tarsodes*, *Dicoma anomala*, *Eriosema angustifolium*, *Geigeria burkei* subsp. *burkei*, *Gerbera ambigua*, *Helichrysum acutatum*, *H. appendiculatum*, *H. cephaloideum*, *H. nudifolium* var. *pilosellum*, *H. oreophilum*, *H. umbraculigerum*, *Indigofera sanguinea*, *Kohautia amatymbica*, *Lobelia flaccida*, *Monsonia attenuata*, *Pearsonia sessilifolia* subsp. *marginata*, *Rabdosiella calycina*, *Selago hyssopifolia*, *Senecio panduriformis*, *S. scitus*, *Vernonia centaureoides*, *V. natalensis*, *V. poskeana*, *Wahlenbergia squamifolia*. Herbaceous Climber: *Rhynchosia caribaea*. Geophytic Herbs: *Asplenium aethiopicum*, *Cheilanthes hirta*, *Pteridium aquilinum*, *Schizocarphus nervosus*. Succulent Herbs: *Crassula alba*, *C. vaginata*, *Craterostigma wilmsii*.

Biogeographically Important Taxa ([N]Northern sourveld endemic, [W]Wolkberg endemic) Small Trees: *Protea rubropilosa*[N] (d), *Encephalartos paucidentatus*[N]. Tall Shrub: *Tricalysia capensis* var. *galpinii*[N]. Low Shrubs: *Asparagus rigidus*[W], *Berkheya carlinopsis* subsp. *magalismontana*[N], *Helichrysum mimetes*[N], *H. reflexum*[N], *H. rudolfii*[N], *H. uninervium*[N], *Hemizygia parvifolia*[N], *H. rehmannii*[W], *H. subvelutina*[N], *Kotschya parvifolia*[N], *Protea parvula*[N], *Sutera polelensis* subsp. *fraterna*[N], *Syncolostemon eriocephalus*[N]. Succulent Shrub: *Aloe chortolirioides* var. *woolliana*[N]. Semiparasitic Shrubs: *Thesium gracilentum*[W], *T. multiramulosum*[N]. Herbs: *Anisopappus junodii*[W], *Cyanotis pachyrrhiza*[N], *Hemizygia transvaalensis*[N], *Monsonia transvaalensis*[N], *Pearsonia aristata*[N], *Scabiosa transvaalensis*[W]. Geophytic Herbs: *Agapanthus inapertus* subsp. *hollandii*[N], *A. inapertus* subsp. *parviflorus*[N], *Aspidonepsis shebae*[N], *Brachystelma stellatum*[N], *Cyrtanthus thorncroftii*[N], *Disa extinctoria*[N], *Gladiolus calcaratus*[N], *G. exiguus*[N], *G. varius*[N], *G. vernus*[N], *Ledebouria minima*[N], *Tulbaghia transvaalensis*[N]. Succulent Herbs: *Aloe affinis*[N], *A. thompsoniae*[W].

Endemic Taxa Small Trees: *Encephalartos brevifoliolatus*, *E. cupidus*, *E. nubimontanus*, *Protea laetans*. Low Shrubs: *Erica rivularis*, *Euclea dewinteri*, *Hemizygia rugosifolia*, *Lopholaena festiva*. Graminoid: *Schoenoxiphium schweickerdtii*. Herbs: *Cineraria hederifolia*, *Inezia speciosa*, *Monopsis kowynensis*, *Monsonia lanuginosa*, *Schistostephium artemisiifolium*, *Streptocarpus decipiens*. Geophytic Herbs: *Brachystelma pachypodium*, *Crocosmia mathewsiana*, *Cyrtanthus huttonii*, *C. junodii*, *Dierama adelphicum*, *Disa aristata*, *Drimiopsis davidsonae*, *Ledebouria* sp. nov. ('*rupestris*'), *L. galpinii*, *L. petiolata*, *Schizochilus crenulatus*, *Tulbaghia coddii*, *T. simmleri*, *Watsonia strubeniae*. Succulent Herb: *Aloe nubigena*.

Conservation Vulnerable. The conservation target is 27% and 15% is protected within the Lekgalameetse and Blyde River Canyon National Park. As much as 38% of this unit has been transformed mainly by plantations (37%), with limited cultivated areas. Estimated erosion potential levels very low (39%), low (47%) and moderate (14%).

Remark 1 This vegetation type closely coincides with the Wolkberg Centre of Endemism and is rich in endemic plants. Although this centre does incorporate the dolomites of Gm 22 Northern Escarpment Dolomite Grassland and SVcb 25 Poung Dolomite Mountain Bushveld, it is also comprised of two subcentres, namely the Serala and Blyde Subcentres. The Serala Subcentre is found to the north of the Olifants River along the Northern Escarpment, with approximately 36 endemics and near-endemics. The Blyde Subcentre is found to the south of the Olifants River along the Northern Escarpment, with approximately 15 endemic or near-endemic species.

Remark 2 Patches of FOz 4 Northern Mistbelt Forest are common in protected rocky areas.

References Smith (1972), Deall (1985), Deall et al. (1989), Stalmans (1990), Matthews (1991), Matthews et al. (1991, 1992a, 1993, 1994), Stalmans & Mentis (1993), Van Wyk & Smith (2001), Emery et al. (2002), Brown et al. (2005).

Gm 24 Northern Escarpment Afromontane Fynbos

VT 8 North-Eastern Mountain Sourveld (92%) (Acocks 1953). LR 2 Afromontane Forest (41%), LR 21 Sour Lowveld Bushveld (22%) (Low & Rebelo 1996).

M.C. Lötter

Figure 8.57 Gm 24 Northern Escarpment Afromontane Fynbos: Montane fynbos shrublands with *Aloe arborescens*, *Cliffortia serpyllifolia*, *Hemizygia albiflora*, *Syncolostemon eriocephalus*, *Eumorphia davyi*, *Podocarpus latifolius* and *Cyrtanthus huttonii* on the summit of Mariepskop (Blyde River Canyon National Park, Mpumalanga).

Distribution Limpopo and Mpumalanga Provinces: Restricted distribution from the peaks of Thabakgolo Mountains above Penge, southwards along highest peaks only, through Mariepskop and as far south as Graskop. Also found in fragments on the summits of the Blouberg and Soutpansberg Mountains (the latter unmapped). Altitude 1 640–1 900 m, with outliers found as low as 1 300 m.

Vegetation & Landscape Features The dominant structural form is shrubland comprised of sclerophyllous shrubs and herbs, many with ericoid growth forms. It occurs in fragmented patches of high-lying quartzite ridges that experience frequent mist. Terrain is very rocky and fires are very rare.

Geology & Soils Predominantly quartzite of the Black Reef Formation and the Wolkberg Group but also on the westerly Timeball Hill Formation and other quartzitic formations of the Pretoria Group (Transvaal Supergroup). The overwhelmingly dominant land type is Ib, with Ac having a subordinate position.

Climate Summer rainfall generally greater than 1 400 mm, augmented by mist during large parts of the year. Temperature cooler than surrounding areas (MAT 15.6°C). Frosts infrequent. See climate diagram for Gm 24 Northern Escarpment Afromontane Fynbos (Figure 8.36).

Important Taxa ([B]Also on Blouberg) Small Trees: *Protea caffra* subsp. *caffra*[B], *P. roupelliae* subsp. *roupelliae*[B]. Tall Shrub: *Psoralea latifolia*. Succulent Shrub: *Aloe arborescens* (d). Low Shrubs: *Anthospermum hispidulum* (d), *Cliffortia nitidula* (d), *C. serpyllifolia* (d), *Erica natalitia* var. *natalitia* (d), *Hypericum revolutum* (d), *Passerina montana* (d), *Cliffortia linearifolia*[B], *Erica revoluta*, *E. simii*[B], *Euryops pedunculatus*, *Helichrysum obductum*, *H. splendidum*, *H. wilmsii*, *Macowania tenuifolia*, *Morella pilulifera*[B], *Myrsine africana*, *Otiophora cupheoides*, *Phylica paniculata*[B], *Phymaspermum acerosum*, *Schistostephium rotundifolium*. Graminoids: *Ischyrolepis schoenoides* (d), *Scleria transvaalensis* (d), *Cyperus pseudoleptocladus*. Herbs: *Plectranthus rubropunctatus* (d), *Blechnum punctulatum*. Geophytic Herb: *Drimia elata*[B].

Biogeographically Important Taxa ([W]Wolkberg endemic, [N]Northern sourveld endemic, [B]Also on Blouberg, [Z]Link to Zimbabwe) Small Trees: *Faurea galpinii*[N], *Protea rubropilosa*[W], *Widdringtonia nodiflora*[B,Z]. Low Shrubs: *Helichrysum rudolfii*[N] (d), *Hemizygia albiflora*[N] (d), *Asparagus rigidus*[W], *Helichrysum mariescopicum*[N], *Leucospermum saxosum*[Z], *Syncolostemon eriocephalus*[N]. Herb: *Anisopappus junodii*[W] (d). Geophytic Herbs: *Agapanthus inapertus* subsp. *pendulus*[N]. Succulent Herb: *Aloe nubigena*[W].

Endemic Taxa Low Shrub: *Eumorphia davyi*. Herb: *Stachys reticulata*. Geophytic Herb: *Gladiolus saxatilis*.

Conservation The conservation target of 27% has been superseded since 56% of the unit enjoys formal protection in the Blyde River Canyon National Park and Mac Mac Conservation Area. The patches on the summits of Blouberg and Soutpansberg also enjoy formal and private protection. The landscape is rugged and soils shallow, therefore very little transformation of this unit has occurred. Transformation levels currently stand at 0.7% (plantations). Erosion very low (35%), low (44%) and moderate (20%).

Remarks This vegetation unit contains a unique combination of plant species with convergent growth forms and taxonomic links to that of the Fynbos Biome with genera such as *Cliffortia*, *Erica*, *Passerina*, *Phylica*, *Protea*, *Ischyrolepis* and *Stoebe*, typical of dystrophic soils. This unit also incorporates a suite of other taxa from the Grassland and Afrotemperate Forest Biomes. Forestry management has increased the exclusion of fires from certain areas and subsequently increased the occurrence of the afromontane fynbos vegetation. Under these conditions, this vegetation type may be a precursor to forest, but establishment of forest may be possible only if the soil is deep enough and the impact of desiccation and frosts can be avoided.

References Van der Schijff (1963), Smith (1972), Matthews (1991).

Gm 25 Woodbush Granite Grassland

VT 8 North-Eastern Mountain Sourveld (93%) (Acocks 1953). LR 43 North-eastern Mountain Grassland (61%) (Low & Rebelo 1996).

Distribution Limpopo Province: Occurs on the Woodbush Plateau and its outliers, to the north of the Wolkberg, on the Groot Letaba watershed west of Duiwelskloof, Tzaneen and Lenyenye. Altitude 1 080–1 800 m.

Vegetation & Landscape Features Mountainous plateau covered by grassland, showing increased low-shrub density on steep south- and east-facing slopes.

Geology & Soils Archaean granite, gneiss and greenstone basement: Turfloop granite (Randian) and relicts of Goudplaats gneiss (Swazian) and occasional dolerite dykes or sills, and quartz veins. Dominant land type Ab, with Hutton (Glenrosa and Shortlands) soils.

Climate Summer rainfall, with MAP from 700 mm in the east to 1 500 mm in the west (MAP 1 166 mm), with peak in January. Some precipitation may also occur in winter. Mist is common and there is an orographic effect on the Escarpment. Temperature is generally lower in the west than in the east (overall MAT 16.6°C). Frost infrequent. See also climate diagram for Gm 25 Woodbush Granite Grassland (Figure 8.36).

Important Taxa Graminoids: *Eragrostis plana* (d), *E. racemosa* (d), *Hyparrhenia hirta* (d), *Microchloa caffra* (d), *Monocymbium ceresiiforme* (d), *Paspalum scrobiculatum* (d), *Stipa dregeana* var. *dregeana* (d), *Themeda triandra* (d), *Alloteropsis semialata* subsp. *eckloniana*, *Andropogon schirensis*, *Cymbopogon nardus*, *Festuca costata*, *Panicum natalense*, *Rendlia altera*. Herbs: *Berkheya echinacea*, *Chamaecrista mimosoides*, *Helichrysum cephaloideum*, *H. nudifolium* var. *pilosellum*, *Hypolepis sparsisora*, *Selago procera*, *Vernonia oligocephala*. Geophytic Herbs: *Asplenium sandersonii* (d), *Agapanthus inapertus* subsp. *inapertus*, *Asplenium lobatum*, *Merwilla natalensis*, *Pteridium aquilinum*. Succulent Herb: *Aloe lettyae*. Tall Shrub: *Tricalysia lanceolata*. Low Shrubs: *Asparagus virgatus*, *Dicliptera clinopodia*, *Eriosema nutans*, *Euryops pedunculatus*, *Hypericum revolutum*, *Protea simplex*.

Biogeographically Important Taxa ([N]Northern sourveld endemic, [Z]Link to Zimbabwe) Succulent Herb: *Huernia insigniflora*[N]. Low Shrub: *Eriosema buchananii*[Z].

Endemic Taxa Herb: *Wahlenbergia brachiata*. Geophytic Herbs: *Chlorophytum radula*, *Kniphofia crassifolia* (extinct). Low Shrub: *Indigofera rehmannii*.

Conservation Critically endangered. Conservation target (27%) can hardly be met since only about 10% of this unit is still in a natural state. There are no conservation areas protecting patches of this unit. The major land transformation is due to silviculture (69%) and to a much lesser degree to cultivation and urban development. Erosion potential very low (7%), low (88%) and moderate (5%). Frequent alien plants include *Acacia mearnsii*, *A. dealbata*, *Prunus serotina*, *Lilium formosanum*, *Agrimonia procera*, *Solanum mauritianum* and

Acanthospermum australe. The vegetation is subject to bush encroachment (from both scrub forest and sour bushveld) exacerbated by exclusion of fire.

Remark 1 This unit is distinct from the Gm 26 Wolkberg Dolomite Grassland, mainly due to the combination of the plateau topography, different geology and soils, and the prevalence of fog frequently precipitating over the plateau. The landscape is similar to higher-lying parts of the Figtree Plateau in the Sabie-White River area.

Remark 2 It is likely that the lower mapped area around Duiwelskloof falls within the sour bushveld rather than in this grassland unit.

References Acocks (1953, 1988), P.J.D. Winter (unpublished data).

Gm 26 Wolkberg Dolomite Grassland

VT 8 North-Eastern Mountain Sourveld (87%) (Acocks 1953). LR 43 North-eastern Mountain Grassland (98%) (Low & Rebelo 1996).

Distribution Limpopo Province: Occurs along the summit of the Strydpoort and Wolkberg Mountains, from the Lekgalameetse Nature Reserve in the east, along the dolomite belt to Mogodi in the west. Altitude 1 260–1 840 m.

Vegetation & Landscape Features Series of broad mountain ridges, broad elevated plateaus and adjacent slopes covered with species-rich short, closed grasslands rich in forbs, often dominated by *Loudetia simplex* and *Diheteropogon amplectens*.

Geology & Soils Malmani dolomites of the Chuniespoort Group (Transvaal Supergroup) form the underlying geology of this area. Dominant land types Ib and Ab, with Fa of subordinate importance.

Climate Summer-rainfall regime, 560–980 mm (MAP 772 mm). The adjacent Escarpment catches most of the orographic precipitation (fog, orographic rain), hence this area falls within a rainshadow. Frost infrequent. See also climate diagram for Gm 26 Wolkberg Dolomite Grassland (Figure 8.36).

Important Taxa Small Trees: *Acacia davyi* (d), *Vitex rehmannii* (d), *Acacia caffra*, *Combretum molle*, *Cussonia paniculata*, *C. transvaalensis*, *Dombeya rotundifolia*, *Faurea rochetiana*, *F. saligna*, *Greyia radlkoferi*, *Lippia javanica*, *Protea caffra* subsp. *caffra*, *P. roupelliae* subsp. *roupelliae*. Tall Shrub: *Protea gaguedi*. Low Shrubs: *Asparagus schroederi, Chrysanthemoides monilifera*. Succulent Shrub: *Aloe vryheidensis*. Graminoids: *Andropogon schirensis* (d), *Brachiaria serrata* (d), *Diheteropogon amplectens* (d), *Heteropogon contortus* (d), *Loudetia simplex* (d), *Monocymbium ceresiiforme* (d), *Rendlia altera* (d), *Setaria sphacelata* (d), *Themeda triandra* (d), *Bewsia biflora*, *Elionurus muticus*, *Eragrostis capensis*, *E. chloromelas*, *E. racemosa*, *Panicum natalense*, *Sporobolus pectinatus*, *Trachypogon spicatus*. Herbs: *Dicoma anomala*, *Gerbera ambigua, Ipomoea atherstonei*, *Oxygonum dregeanum*, *Xerophyta retinervis, X. schlechteri*. Succulent Herb: *Aloe fosteri*. Semiparasitic Herb: *Buchnera longespicata*.

Biogeographically Important Taxa (all Northern sourveld endemics) Low Shrubs: *Berkheya pauciflora*, *Heteromorpha pubescens*. Herbaceous Climber: *Cyphia transvaalensis*.

Endemic Taxa Succulent Shrubs: *Aloe dolomitica*, *Euphorbia restricta*. Herbs: *Barleria dolomitica*, *Becium citriodorum*, *B. coddii*, *Dicliptera fionae*, *Lotononis pariflora*.

Conservation Least threatened. The conservation target of 27% has been superseded since more than 48% of this unit is formally protected within the Bewaarkloof and Lekgalameetse Nature Reserves as well as the Wolkberg Wilderness Area. Only a very small portion of this unit has been transformed by plantations. Erosion potential very low (49%), low (36%) and moderate (16%).

Remarks This unit forms the core of the Wolkberg CE, divided further into two subcentres—the Serala and Blyde Subcentres (Van Wyk & Smith 2001).

References Acocks (1953, 1988), Stalmans (1990), Matthews et al. (1993), Stalmans et al. (1997), Van Wyk & Smith (2001).

M. Stalmans

Figure 8.58 Gm 26 Wolkberg Dolomite Grassland: Rocky grassland on dolomite on the Farm The Downs near Makwens in the Lekgalameetse Nature Reserve (Mpumalanga) with *Aloe marlothii*, *Boophone disticha* and the shrub *Parinari curatellifolia*.

Gm 27 Strydpoort Summit Sourveld

VT 8 North-Eastern Mountain Sourveld (62%) (Acocks 1953). LR 43 North-eastern Mountain Grassland (59%) (Low & Rebelo 1996).

Distribution Limpopo Province: A series of isolated patches in high-lying areas of the Strydpoortberge, from Bewaarkloof in the east as far as the mountains just above Mokopane (Potgietersrus) in the west. Altitude largely 1 440–1 800 m, but up to 1 940 m.

Vegetation & Landscape Features Short to tall grasslands along rocky summits and mountain slopes. The landscape has a very broken topography with deeply incised valleys. The slopes are steep and rocky, and sparsely wooded.

Geology and Soils Acidic sandy soil derived from sandstone, quartzite and shale of the Wolkberg Group and the Black Reef Formation as well as the

Pretoria Group in the westernmost parts. In the eastern half of this area a large part is underlain by the Penge Banded Iron Formation of the Chuniespoort Group. All of the above form part of the Transvaal Supergroup. Dominant land type Ib.

Climate Strongly seasonal, with precipitation in summer. Rainfall 530–870 mm (MAP 686 mm). Frost infrequent. See also climate diagram for Gm 27 Strydpoort Summit Sourveld (Figure 8.36).

Important Taxa Small Trees: *Acacia caffra* (d), *Combretum molle* (d), *Cussonia paniculata* (d), *Englerophytum magalismontanum* (d), *Protea caffra* subsp. *caffra* (d), *Cussonia transvaalensis*, *Faurea saligna*, *Mundulea sericea*, *Protea roupelliae* subsp. *roupelliae*, *P. rubropilosa*, *Vangueria infausta*. Tall Shrub: *Rhus dentata*. Woody Climbers: *Ancylobotrys capensis*, *Rhoicissus tridentata*. Low Shrubs: *Rhus magalismontana* (d), *Aeschynomene rehmannii*, *Anthospermum hispidulum*, *Chrysanthemoides monilifera* subsp. *septentrionalis*, *Justicia betonica*, *Leonotis ocymifolia*, *Polygala hottentotta*. Graminoids: *Aristida transvaalensis* (d), *Loudetia simplex* (d), *Monocymbium ceresiiforme* (d), *Schizachyrium sanguineum* (d), *Themeda triandra* (d), *Trachypogon spicatus* (d), *Tristachya leucothrix* (d), *Alloteropsis semialata* subsp. *eckloniana*, *Andropogon chinensis*, *Bulbostylis burchellii*, *Diheteropogon amplectens*, *D. filifolius*, *Elionurus muticus*, *Eragrostis racemosa*, *Sporobolus pectinatus*. Herbs: *Acalypha angustata*, *Helichrysum nudifolium* var. *nudifolium*, *Monsonia attenuata*, *Pearsonia sessilifolia* subsp. *sessilifolia*, *Rhynchosia monophylla*, *Selaginella dregei*, *Vernonia galpinii*, *V. natalensis*, *Xerophyta retinervis*. Herbaceous Climber: *Rhynchosia totta*. Succulent Herbs: *Aloe fosteri*, *Crassula swaziensis*, *Kleinia stapeliiformis*.

Biogeographically Important Taxa ([N]Northern sourveld endemic, [W]Wolkberg endemic) Small Trees: *Encephalartos eugene-maraisii*[N], *Protea rubropilosa*[W]. Tall Shrub: *Vitex obovata* subsp. *wilmsii*[N]. Low Shrubs: *Berkheya carlinopsis* subsp. *magalismontana*[N], *Helichrysum uninervium*[N]. Succulent Herbs: *Aloe affinis*[N], *A. thompsoniae*[W].

Endemic Taxa Succulent Shrub: *Thorncroftia media*. Semiparasitic Shrub: *Thesium gracilentum*. Herb: *Aster nubimontis*.

Conservation Least threatened. Target 24%. About 17% of the area enjoys statutory protection in the Bewaarkloof Nature Reserve. A further small portion is protected in the Wolkberg Wilderness Area. Transformation levels are very low. Erosion potential also very low (73%), low (17%) and moderate (10%).

Remark This unit shares several elements with the Gm 29 Waterberg-Magaliesberg Summit Sourveld, such as *Encephalartos eugene-maraisii* and *Vitex obovata* subsp. *wilmsii*.

References Stalmans & De Klerk (1991, 1992).

Gm 28 Soutpansberg Summit Sourveld

VT 20 Sour Bushveld (77%) (Acocks 1953). LR 11 Soutpansberg Arid Mountain Bushveld (98%) (Low & Rebelo 1996).

Distribution Limpopo Province: Confined to the higher-lying crests and plateaus situated above 1 200 m above sea level and include the highest peaks on the Soutpansberg (Letjuma, 1 747 m) and still higher Blouberg (2 051 m).

Vegetation & Landscape Features Rugged summit crests and adjacent steep rocky slopes supporting a mosaic of low, wiry, closed grasslands and scattered closed-canopy bush clumps. The extent of the bush clumps within the grasslands depends largely on the extent of rock outcrops, rock boulders and the local soil depth. Due to frequent mist the surface of rocks and woody vegetation support rich epilithic and epiphytic lichen and bryophyte flora.

Geology & Soil Sandstone, quartzite and shale of Mokolian age (Soutpansberg Group, Wyllie's Poort Formation) giving rise to extremely shallow, coarse-sand Glenrosa and Mispah soils. These soils drain quickly, leading to leached and acidic conditions. The impermeable rock beds on the relatively flat plateaus often prevent water from draining away, leading to the formation of temporary rock pools. The deeper soils may function as sponges, slowly releasing water to feed mountain streams over prolonged periods. Dominant land type Ib, with Fa of minor importance.

Climate Summer rainfall, with most rain falling between November and February. Van Wyk & Smith (2001) mention precipitation to be as high as 2 000 mm on the highest peaks. The higher-lying crests and ridges are exposed to strong winds. During the summer months, these winds carry moisture in from the Indian Ocean, covering the vegetation in mist almost daily. During the prolonged dry season, the prevailing winds cause dehydration and desiccation of the soils and vegetation (Hahn 2002). Frost infrequent and MAT 16–17°C. See also climate diagram for Gm 28 Soutpansberg Summit Sourveld (Figure 8.36).

Important Taxa ([B]Also Blouberg) Small Trees: *Acacia caffra* (d), *Combretum molle* (d), *Englerophytum magalismontanum* (d), *Protea caffra* subsp. *caffra* (d), *Cussonia natalensis*, *Faurea saligna*[B], *Mundulea sericea*, *Protea roupelliae* subsp. *roupelliae*, *Vangueria infausta*. Tall Shrubs: *Euryops brevipapposus*[B], *Hyperacanthus amoenus*, *Rhus dentata*. Woody Climber: *Ancylobotrys capensis*. Low Shrubs: *Aeschynomene rehmannii*, *Anthospermum hispidulum*, *Erica woodii*[B], *Justicia betonica*, *Leonotis ocymifolia*, *Myrsine africana*, *Passerina montana*, *Polygala hottentotta*. Succulent Shrub: *Cotyledon barbeyi*. Graminoids: *Aristida transvaalensis* (d), *Monocymbium ceresii-*

D. Gwynne-Evans

Figure 8.59 Gm 28 Soutpansberg Summit Sourveld: Local endemic shrub *Callilepis caerulea* (Asteraceae) on a ridge of the Soutpansberg (Limpopo Province).

forme (d), *Schizachyrium sanguineum* (d), *Themeda triandra* (d), *Trachypogon spicatus* (d), *Andropogon chinensis*, *Bulbostylis burchellii*, *Diheteropogon amplectens*, *Eragrostis racemosa*, *Ischyrolepis schoenoides*[B], *Panicum maximum*, *Pentaschistis natalensis*[B], *Tristachya rehmannii*. Herbs: *Acalypha angustata*, *Helichrysum nudifolium* var. *nudifolium*, *H. subglomeratum*[B], *Rhynchosia monophylla*, *Selaginella dregei*, *Tephrosia purpurea* subsp. *leptostachya*, *Vernonia galpinii*, *Waltheria indica*, *Xerophyta retinervis*. Herbaceous Climber: *Rhynchosia totta*. Geophytic Herb: *Agapanthus inapertus* subsp. *intermedius*[B]. Succulent Herb: *Crassula swaziensis*.

Biogeographically Important Taxa ([B]Also on Blouberg, [N]Northern sourveld endemic, [S]Soutpansberg endemic) Low Shrubs: *Berkheya carlinopsis* subsp. *magalismontana*[N], *Eriocephalus longifolius*[N]. Herb: *Tetraselago wilmsii*[N]. Geophytic Herbs: *Agapanthus dyeri*[N,B], *Cyrtanthus thorncroftii*[N]. Succulent Herb: *Aloe vossii*[S].

M.C. Rutherford

Figure 8.60 Gm 29 Waterberg-Magaliesberg Summit Sourveld: Grassland on the summit of the Magaliesberg viewed from an altitude of 1 770 m in the Magaliesberg Conservation Area, south of the Krom River near Rustenburg (North-West Province).

Endemic Taxa Tall Shrub: *Callilepis caerulea*. Low Shrubs: *Rhus magalismontana* subsp. *coddii* (d). Succulent Shrubs: *Delosperma zoutpansbergense*, *Khadia borealis*. Succulent Herb: *Aloe soutpansbergensis*.

Conservation Least threatened. Target 24%. About 18% statutorily conserved in the Blouberg and Happy Rest Nature Reserves and further in the private Soutpansberg Conservancy. Some of the area is transformed by *Eucalyptus* and *Pinus* plantations. Overgrazing by cattle and donkeys and inappropriate introduction of game from savanna plains are recognised as further threats to this vegetation unit. Erosion very low (52%) and low (39%).

Remarks This unit is part of the Soutpansberg Centre of Endemism (Van Wyk & Smith 2001). Pockets of Gm 24 Northern Escarpment Afromontane Fynbos and FOz 4 Northern Mistbelt Forest border on this summit grassland sourveld.

References Scholes (1979), Van Wyk & Smith (2001), Hahn (2002).

Gm 29 Waterberg-Magaliesberg Summit Sourveld

Distribution Limpopo and North-West Provinces and marginally into Gauteng: Isolated patches on summits of the Waterberg (including the Sandrivierberge, Hoekberge, Hanglipberge and Swaershoekberge), Pilanesberg (not mapped) and Magaliesberg. Altitude 1 500–2 088 m in the Waterberg, 1 853 m in the Magaliesberg and 1 687 m in the Pilanesberg.

Vegetation & Landscape Features Higher slopes and summit positions including crests, and steep rocky scarps and cliff faces, covered with grassland (and accompanying rocky outcrops) dominated by wiry tussock grasses. Patches of open *Protea caffra* savannoid vegetation and open shrubland with *Englerophytum magalismontanum* and *Landolphia capensis* are common and typical of this sourveld vegetation type.

Geology and Soils Acidic sandy, loamy to gravel soil derived from coarse, clastic sedimentary sandstone, quartzite, conglomerate or shale of the Kransberg Subgroup (Waterberg Group, Mokolian Erathem). Ib and Fa land types (both 42%) are co-dominant, with Ac covering a smaller area (12%).

Climate Summer rainfall, with MAP 710 mm. Cool-temperate climate (MAT close to 16°C) due to higher altitude. Frost fairly infrequent. See also climate diagram for Gm 29 Waterberg-Magaliesberg Summit Sourveld (Figure 8.36).

Important Taxa ([R]Mainly on rocky outcrops) Small Trees: *Englerophytum magalismontanum* (d), *Protea caffra* subsp. *caffra* (d), *P. roupelliae* subsp. *roupelliae* (d), *Acacia caffra*, *Brachylaena rotundata*, *Combretum moggii*, *C. molle*, *Faurea saligna*, *Vangueria infausta*, *Zanthoxylum capense*. Tall Shrubs: *Elephantorrhiza burkei*, *Indigofera comosa*[R], *Protea gaguedi*, *Rhus dentata*. Woody Climber: *Ancylobotrys capensis* (d). Low Shrubs: *Lopholaena coriifolia*[R] (d), *Passerina montana* (d), *Rhus magalismontana* (d), *Acalypha angustata*, *Aeschynomene rehmannii*, *Anthospermum hispidulum*, *A. rigidum* subsp. *rigidum*, *Erica drakensbergensis*, *Euryops pedunculatus*, *Myrothamnus flabellifolius*[R], *Myrsine africana*, *Polygala hottentotta*, *Protea welwitschii*, *Rhynchosia nitens*, *Tephrosia longipes*. Succulent Shrubs: *Euphorbia clavarioides* var. *truncata*[R], *E. schinzii*[R], *Raphionacme burkei*[R]. Semiparasitic Shrubs: *Thesium transvaalense*, *T. utile*. Geoxylic Suffrutices: *Elephantorrhiza elephantina*, *Parinari capensis*. Graminoids: *Aristida transvaalensis* (d), *Bulbostylis burchellii* (d), *Coleochloa setifera*[R] (d), *Diheteropogon amplectens* (d), *Eragrostis nindensis*[R] (d), *Loudetia simplex* (d), *Melinis nerviglumis* (d), *Schizachyrium sanguineum* (d), *Trachypogon spicatus* (d), *Tristachya biseriata* (d), *Andropogon schirensis*, *Aristida aequiglumis*, *Brachiaria serrata*, *Cymbopogon caesius*, *Cyperus rupestris*[R], *Digitaria brazzae*, *Eragrostis racemosa*, *E. stapfii*[R], *Microchloa caffra*[R], *Monocymbium ceresiiforme*, *Panicum natalense*, *Themeda triandra*, *Tristachya rehmannii*. Herbs: *Selaginella dregei* (d), *Acalypha angustata*, *Commelina africana*, *C. erecta*, *Helichrysum nudifolium* var. *nudifolium*, *Indigofera hedyantha*, *I. melanadenia*, *Ipomoea ommaneyi*, *Nidorella hottentotica*, *Oldenlandia herbacea*, *Pseudognaphalium undulatum*, *Rhynchosia monophylla*, *Vernonia galpinii*, *Xerophyta retinervis*[R]. Herbaceous Climber: *Rhynchosia totta*. Geophytic Herbs: *Albuca setosa*[R], *Lapeirousia sandersonii*[R], *Ledebouria marginata*, *Pellaea calomelanos*. Succulent Herb: *Crassula lanceolata* subsp. *transvaalensis*.

Biogeographically Important Taxa ([N]Northern sourveld endemic, [R]Mainly on rocky outcrops) Small Tree: *Encephalartos*

eugene-maraisii[N]. Low Shrubs: *Berkheya carlinopsis* subsp. *magalismontana*[N], *Eriocephalus longifolius*[N], *Helichrysum uninervium*[N]. Succulent Shrubs: *Adromischus umbraticola*[N], *Aloe peglerae*[N]. Herb: *Cyanotis pachyrrhiza*[N]. Geophytic Herb: *Ledebouria minima*[N]. Succulent Herbs: *Frithia pulchra*[N,R], *Khadia acutipetala*[N,R].

Conservation Least threatened. Target of 24% has already been achieved since more than 27% of the unit is statutorily conserved in the Marekele National Park, Entabeni Nature Reserve, Magaliesberg Nature Area (including the Rustenburg Nature Reserve). The unmapped portion in the Pilanesberg Game Park is fully conserved. A further 4% enjoys protection in private conservation areas. Only a very small area transformed. Erosion low (60%) and very low (34%).

Remark 1 Embedded within this sourveld there are abundant rocky sheets found on exposed mountain tops and ridges, supporting sparse edaphic grassland/herbland with classical resurrection plants such as *Myrothamnus flabellifolius* and *Selaginella dregei*. It is here where succulents (some endemic) of the genera *Frithia*, *Khadia* and *Delosperma* (Aizoaceae), *Adromischus* (Crassulaceae), *Anacampseros* (Portulacaceae) and numerous low succulent representatives of *Euphorbia* are found.

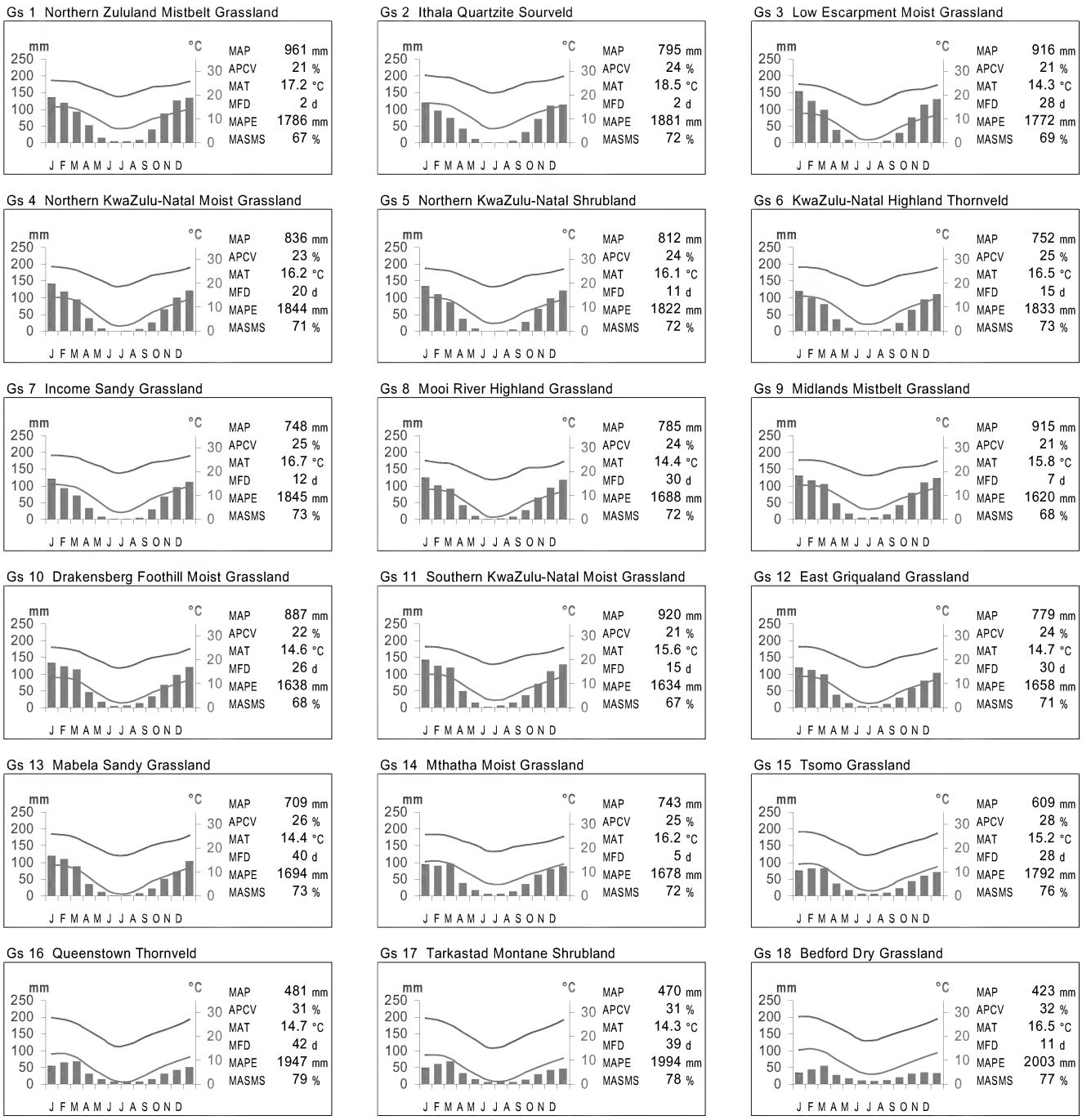

Figure 8.61 Climate diagrams of the Sub-Escarpment Grassland Bioregion units. Blue bars show the median monthly precipitation. The upper and lower red lines show the mean daily maximum and minimum temperature respectively. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days (days when screen temperature was below 0°C); MAPE: Mean Annual Potential Evaporation; MASMS: Mean Annual Soil Moisture Stress (% of days when evaporative demand was more than double the soil moisture supply).

Remark 2 We are aware of the existence of patches of this unit on the highest summits of the Pilanesberg near Rustenberg in the North-West Province, but have not been able to map them due to lack of sufficient data.

References Acocks (1953, 1988), Coetzee (1974, 1975), Coetzee & Werger (1975), Van der Meulen (1979a, b), Westfall (1981), Burgoyne et al. (2000), Van Staden (2002), Bredenkamp & Brown (2003), Van Staden & Bredenkamp (2005).

I. Johnson

Figure 8.62 Gs 1 Northern Zululand Mistbelt Grassland: Species-rich grasslands on the Ngome Mountain between Nongoma and Vryheid.

Sub-Escarpment Grassland

Sub-Escarpment Grassland is found on the rolling hills and flat plains of the foothills of the Drakensberg and Northern Escarpment. The physical nature of these areas is determined by the rate at which the landscape ascends into the main Escarpment region as well as the degree to which the landscape has been shaped by geomorphological forces. The result is a diversity of land forms, including rolling hills, such as the Valley of a Thousand Hills in KwaZulu-Natal, and flat plains such as those found south of the Amathole Mountains. A strong decrease in rainfall can be observed in the Sub-Escarpment Grassland from northeast to southwest (Figure 8.61). In areas with undulating landscapes, common in Transkei and KwaZulu-Natal, the orographic influence of the rising landscape furthermore results in regular mists in these areas and thus the formation of numerous mistbelt regions.

Gs 1 Northern Zululand Mistbelt Grassland

VT 64 Northern Tall Grassveld (Transition between Piet Retief Sourveld and Southern Tall Grassveld) (46%), VT 8 North-Eastern Mountain Sourveld (36%) (Acocks 1953). LR 25 Natal Central Bushveld (59%) (Low & Rebelo 1996). BRG 11 Moist Transitional Tall Grassveld (47%), BRG 7 Northern Mistbelt (31%) (Camp 1999a).

Distribution KwaZulu-Natal Province: Crests and slopes of the Ngome Mountain range and the Ngoje Mountain surrounding Louwsburg as well as some smaller mountainous areas of Langkrans, KwaCeza, KwaNtimbankulu and Nhlazatshe. Altitude 780–1 540 m.

Vegetation & Landscape Features Gentle to steep upper slopes of mountains formed by hard dolerite dykes dominated by relatively forb-rich, tall sour *Themeda triandra* grasslands.

Geology & Soils Shales and sandstones of the Madzaringwe and Pietermaritzburg Formations (both Karoo Supergroup) as well as intrusive rocks of the Karoo Dolerite Suite. Dominant soil forms are Hutton, Clovelly and Griffin and are well drained, having 15–35% clay in the A-horizon. Dominant land type Ac, followed in importance by Fa and Ab.

Climate Summer rainfall, with overall MAP around 960 mm, reaching 1 130 mm in places. Moisture-laden air frequently blows in from the southeast and is forced up 400–500 m over the mountains, creating 'mistbelt' conditions (particularly in spring and summer) that contribute to precipitation. MAT is 17.2°C (16–17.4°C) and mean annual range of evaporation is close to 1 790 mm. See also climate diagram for Gs 1 Northern Zululand Mistbelt Grassland (Figure 8.61).

Important Taxa Graminoids: *Themeda triandra* (d), *Tristachya leucothrix* (d), *Alloteropsis semialata* subsp. *eckloniana*, *Andropogon schirensis*, *Aristida monticola*, *Brachiaria serrata*, *Cymbopogon nardus*, *Cyperus albostriatus*, *Ehrharta erecta* var. *erecta*, *Elionurus muticus*, *Eragrostis plana*, *E. racemosa*, *Hyparrhenia hirta*, *Loudetia simplex*, *Microchloa caffra*, *Monocymbium ceresiiforme*, *Panicum deustum*, *Paspalum scrobiculatum*, *Rendlia altera*, *Schizachyrium sanguineum*, *Setaria nigrirostris*, *Sporobolus africanus*, *Trachypogon spicatus*. Herbs: *Aeschynomene micrantha*, *Conostomium natalense*, *Helichrysum chionosphaerum*, *H. nanum*, *H. nudifolium* var. *oxyphyllum*, *H. nudifolium* var. *pilosellum*, *H. umbraculigerum*, *Hermannia grandistipula*. Geophytic Herbs: *Cheilanthes hirta*, *Oxalis smithiana*, *Watsonia latifolia*. Small Tree: *Apodytes dimidiata* subsp. *dimidiata*. Low Shrubs: *Asparagus virgatus*, *Clutia pulchella*. Succulent Shrub: *Aloe arborescens*.

Biogeographically Important Taxon (Low Escarpment endemic) Herb: *Melanospermum italae*.

Endemic Taxa Herbs: *Dracosciadium italae*, *Helichrysum ingomense*, *Selago barbula*. Geophytic Herbs: *Brachystelma ngomense*, *Dierama erectum*, *Schizoglossum ingomense*.

Conservation Vulnerable. Target 23%. Only about 3% statutorily conserved in the Ithala Nature Reserve and in the Ntendeka Wilderness Area of the Ngome State Forest (Scott-Shaw et al. 1996, Scott-Shaw 1999). Some 22% has been transformed for plantations or cultivated land. Threats to the remaining grasslands are heavy selective grazing by livestock and extensive annual burning. Spread of alien *Acacia mearnsii* and *Eucalyptus* species is of serious concern. Erosion very low (47%), moderate (29%), low (14%) and high (10%).

Remarks This vegetation unit surrounds a large patch of Northern Midlands Mistbelt Forest (Von Maltitz et al. 2003) at Ngome. Camp (1999a) indicated that a striking difference between this unit and his BRG 5 and BRG 7 (constituting Midlands Mistbelt Grassland) is the lack of *Aristida junciformis* subsp. *junciformis*. A number of endemic species confined to the region of the Northern Zululand Mistbelt Grassland add to this differentiation.

References Acocks (1953, 1988), Scott-Shaw et al. (1996), Camp (1999a), Scott-Shaw (1999),

Gs 2 Ithala Quartzite Sourveld

VT 64 Northern Tall Grassveld (Transition between Piet Retief Sourveld and Southern Tall Grassveld) (34%), VT 10 Lowveld (32%) (Acocks 1953). LR 43 North-eastern Mountain Grassland (54%) (Low & Rebelo 1996). BRG 20 Dry Zululand Thornveld (42%), BRG 16 Dry Lowland Tall Grassveld (9%) (Camp 1999c, d).

Distribution KwaZulu-Natal and Mpumalanga Provinces and Swaziland: Confined to large quartzite patches that occur from Amsterdam, southwards east of Piet Retief and through Mahamba, to the Paris Dam and Ithala Game Reserve, with isolated outcrops near Magudu. Altitude 440–1 360 m.

Vegetation & Landscape Features Low mountain ranges and undulating hills with rocky lowlands. The general pattern is a mosaic of woody shrubs and small trees in rocky areas, interspersed in the grass layer. Vegetation structure varies according to altitude and rockiness, but the basal density of the grass sward is relatively low. This unit occurs in the zone between Grassland and Savanna where the dominant grassland gives way to woodland as elevation decreases. The grasslands are species-rich covering a variety of altitudes but sharing common species unique to the dystrophic quartzite geology.

Geology & Soils Quartzite of the Mozaan Group (Pongola Supergroup) of the Randian age supporting shallow soils typical of Fb (prevalent) and Fa (marginal) land types.

Climate Rainfall peaks in midsummer. MAP from about 1 200 mm in the west to 570 mm in the east (MAP 795 mm). Frost does occur, but is infrequent. See also climate diagram for Gs 2 Ithala Quartzite Sourveld (Figure 8.61).

Important Taxa Small Trees: *Combretum molle* (d), *Englerophytum magalismontanum* (d), *Syzygium legatii* (d), *Acacia caffra*, *A. davyi*, *Cassipourea swaziensis*, *Cussonia natalensis*, *Dombeya cymosa*, *Faurea rochetiana*, *F. saligna*, *Ficus burtt-davyi*, *Lannea discolor*, *Pachystigma macrocalyx*, *Pavetta edentula*, *Protea caffra* subsp. *caffra*, *P. roupelliae* subsp. *roupelliae*, *Pterocarpus angolensis*. Tall Shrubs: *Morella pilulifera* (d), *Pavetta gracilifolia* (d), *Protea gaguedi*, *Rhus pallens*, *R. pentheri*. Woody Climber: *Jasminum multipartitum*. Low Shrubs: *Gymnosporia tenuispina* (d), *Helichrysum lepidissimum* (d), *Lopholaena platyphylla*. Succulent Shrub: *Crassula sarcocaulis*. Graminoids: *Heteropogon contortus* (d), *Hyperthelia dissoluta* (d), *Loudetia simplex* (d), *Monocymbium ceresiiforme* (d), *Panicum natalense* (d), *Themeda triandra* (d), *Trachypogon spicatus* (d), *Bothriochloa insculpta*, *Diheteropogon amplectens*, *Melinis nerviglumis*, *Pogonarthria squarrosa*, *Sporobolus pectinatus*. Herbs: *Anisopappus smutsii* (d), *Xerophyta retinervis*. Succulent Herb: *Aloe cooperi* subsp. *cooperi*. Succulent Herbaceous Climber: *Ceropegia sandersonii*.

Biogeographically Important Taxa ([L]Low Escarpment endemic, [N]Northern sourveld endemic) Small Tree: *Protea comptonii*[N]. Tall Shrub: *Tricalysia capensis* var. *galpinii*[N] (d). Low Shrub: *Hemizygia macrophylla*[L]. Succulent Shrub: *Aloe suprafoliata*[N] (d). Herbs: *Melanospermum italae*[L], *Thorncroftia longiflora*[N]. Geophytic Herb: *Gladiolus vernus*[N].

Endemic Taxa Tall Shrub: *Euclea natalensis* subsp. *maguten-sis*. Succulent Shrub: *Aloe dewetii*. Graminoid: *Danthoniopsis scopulorum*. Geophytic Herb: *Gladiolus scabridus*.

Conservation Least threatened. The target of 27% has not been reached. A total of 10% of this unit is protected within the Ithala Game Reserve. Land use pressures on this unit are low, probably because of its low nutrient status and rocky nature. Approximately 5% is under plantations and a further 5% has been transformed into cultivated land. Soil erosion potential is low.

Remarks This naturally fragmented vegetation unit is characterised by its rocky and nutrient-poor soils which support a unique assemblage of plant species. It shares some species with the nutrient-poor soils of the Northern Escarpment (e.g. *Syzygium legatii*) and Barberton areas (e.g. *Thorncroftia longiflora*, *Protea comptonii*). These latter units have a higher MAP.

References Acocks (1953, 1988), M.C. Lötter (unpublished data).

Gs 3 Low Escarpment Moist Grassland

VT 44 Highland Sourveld and Dohne Sourveld (54%) (Acocks 1953). LR 41 Wet Cold Highveld Grassland (54%) (Low & Rebelo 1996). BRG 8 Moist Highland Sourveld (70%) (Camp 1999b).

M.C. Lötter

Figure 8.63 Gs 2 Ithala Quartzite Sourveld: Sparse rocky grassland with shrubby *Englerophytum magalismontanum*, *Aloe suprafoliata* and *Acacia karroo* on quartzite ridges in the Ithala Game Reserve (northern KwaZulu-Natal).

Distribution KwaZulu-Natal, Free State and Mpumalanga Provinces: Slopes of the Drakensberg, on both sides of the provincial boundary from Oliviershoek (near Harrismith) to Volksrust. Altitude 1 300–2 000 m.

Vegetation & Landscape Features Complex mountain topography. Steep, generally east- and south-facing slopes, with a large altitudinal range. Supporting tall, closed grassland with *Hyparrhenia hirta* and *Themeda triandra* dominant. *Protea caffra* communities and patches of *Leucosidea* scrub feature at higher altitudes.

Geology & Soils Ecca and Beaufort Groups (Karoo Supergroup) mudstone or shale. Soils are mainly of the Hutton form, but also shallower forms such as Glenrosa and Mispah. Half of the area is classified as Fa land type, while the rest is shared among Ac, Bb and Ad land types.

Climate Summer rainfall, with peak from December to January. Frequent fog adds

to the overall precipitation. MAP is almost 920 mm and mean annual evaporation reaches 1 770 mm. MAT of 14.3°C and almost 30 days of frost indicate that the unit is found close to the lower limit of warm-temperate climate. See also climate diagram for Gs 3 Low Escarpment Moist Grassland (Figure 8.61).

Important Taxa Graminoids: *Alloteropsis semialata* subsp. *eckloniana* (d), *Andropogon schirensis* (d), *Diheteropogon filifolius* (d), *Eragrostis plana* (d), *Hyparrhenia hirta* (d), *Monocymbium ceresiiforme* (d), *Themeda triandra* (d), *Trachypogon spicatus* (d), *Tristachya leucothrix* (d), *Andropogon appendiculatus*, *Brachiaria serrata*, *Brachypodium flexum*, *Cynodon dactylon*, *C. transvaalensis*, *Digitaria diagonalis*, *D. monodactyla*, *D. tricholaenoides*, *Diheteropogon amplectens*, *Eragrostis capensis*, *E. chloromelas*, *E. curvula*, *E. gummiflua*, *E. racemosa*, *Harpochloa falx*, *Hyparrhenia tamba*, *Koeleria capensis*, *Loudetia simplex*, *Panicum ecklonii*, *P. natalense*. Herbs: *Acanthospermum australe* (d), *Vernonia natalensis* (d), *Acalypha depressinerva*, *Adenocline acuta*, *Berkheya rhapontica* subsp. *rhapontica*, *Corchorus confusus*, *Crabbea acaulis*, *Cucumis zeyheri*, *Eriosema cordatum*, *Graderia scabra*, *Haplocarpha scaposa*, *Helichrysum miconiifolium*, *H. oreophilum*, *H. psilolepis*, *H. rugulosum*, *H. spiralepis*, *Kohautia amatymbica*, *Lotononis procumbens*, *Nidorella anomala*, *Pentanisia prunelloides* subsp. *latifolia*, *Selago densiflora*, *Senecio venosus*, *Zaluzianskya microsiphon*. Herbaceous Climber: *Rhynchosia totta*. Geophytic Herbs: *Corycium dracomontanum*, *C. nigrescens*, *Gladiolus crassifolius*, *Habenaria dives*, *Hypoxis hemerocallidea*, *H. multiceps*, *H. rigidula* var. *pilosissima*, *Pteridium aquilinum*. Low Shrubs: *Anthospermum rigidum* subsp. *pumilum*, *Chaetacanthus burchellii*, *Clutia pulchella*, *Gnidia kraussiana*, *Helichrysum hypoleucum*, *H. infaustum*, *Phyllanthus glaucophyllus*.

Biogeographically Important Taxon (Low Escarpment endemic) Low Shrub: *Heteromma krookii*.

Endemic Taxon Geophytic Herb: *Holothrix majubensis*.

Conservation Least threatened. Target 23%. Only 2% statutorily conserved in the Sterkfontein Dam Nature Reserve (Free State) and Ncandu Nature Reserve (KwaZulu-Natal). About 6% has been transformed by plantations or cultivated land. Alien *Acacia dealbata* occurs in places. Erosion very low (56%) and low (38%).

Remark A series of patches of Northern KwaZulu-Natal Mistbelt Forests (see Von Maltitz et al. 2003) are embedded within this type of grassland in sub-escarpment regions and deep-kloof positions.

References Acocks (1953, 1988), Edwards (1967), Smit (1992), Smit et al. (1992, 1993b, 1995a, b), Camp (1999b).

Gs 4 Northern KwaZulu-Natal Moist Grassland

VT 65 Southern Tall Grassveld (70%) (Acocks 1953). LR 43 North-eastern Mountain Grassland (53%) (Low & Rebelo 1996). BRG 11 Moist Transitional Tall Grassveld (54%) (Camp 1999a).

Distribution KwaZulu-Natal Province: Northern and northwestern regions of the Province, where it forms a discontinuous rim around the upper Thukela Basin and is situated almost entirely within the catchment of the Thukela River. It lies between the drier Gs 6 KwaZulu-Natal Highland Thornveld and the moist upland vegetation of mainly Gs 3 Low Escarpment Moist Grassland to the north and Gs 10 Drakensberg Foothill Moist Grassland to the west. The most extensive areas are in the vicinity of Winterton, Bergville, Fort Mistake, Dannhauser, Dundee, north of Ladysmith and west of Newcastle. At higher altitudes this unit is usually surrounded by Gs 3 Low Escarpment Moist Grassland in the north and Gs 10 Drakensberg Foothill Moist Grassland in the west and south. At lower altitudes Gs 6 KwaZulu-Natal Highland Thornveld and SVs 2 Thukela Thornveld usually occur to the east. Altitude 1 040–1 440 m.

Vegetation & Landscape Features Hilly and rolling landscapes supporting tall tussock grassland usually dominated by *Themeda triandra* and *Hyparrhenia hirta*. Open *Acacia sieberiana* var. *woodii* savannoid woodlands encroach up the valleys, usually on disturbed (strongly eroded) sites.

Geology & Soils Mudstones, sandstones and shales of the Beaufort and Ecca Groups of the Karoo Supergroup predominate and are intruded by dolerites of Jurassic age. Land types Bb, Ac, Fa and Ca.

Climate Summer rainfall, with overall MAP of 840 mm (710–1 120 mm; Camp 1999a), mainly as summer thunderstorms. Mist occurs frequently on hilltops in spring and early summer, but summer droughts are also frequent. Summers are warm to hot, with maximum temperature recorded in the hottest month of January (Bergville MAT 27.8°C). MAT is around 16°C, but some localities may reach 17°C. Frosts are severe and occur about 20 days per year. Mean annual evaporation recorded at Bergville is 1 895 mm. See also climate diagram for Gs 4 Northern KwaZulu-Natal Moist Grassland (Figure 8.61).

Important Taxa Graminoids: *Alloteropsis semialata* subsp. *eckloniana* (d), *Aristida congesta* (d), *Cynodon dactylon* (d), *Digitaria tricholaenoides* (d), *Elionurus muticus* (d), *Eragrostis patentissima* (d), *E. racemosa* (d), *Harpochloa falx* (d), *Hyparrhenia hirta* (d), *Themeda triandra* (d), *Tristachya leucothrix* (d), *Abildgaardia ovata*, *Andropogon appendiculatus*, *A. eucomus*, *A. schirensis*, *Aristida junciformis* subsp. *galpinii*, *Brachiaria serrata*, *Cymbopogon caesius*, *C. pospischilii*, *Cynodon incompletus*, *Digitaria monodactyla*, *D. san-*

P.J. du Preez

Figure 8.64 Gs 4 Northern KwaZulu-Natal Moist Grassland: Savannoid grasslands with *Acacia sieberiana* var. *woodii* near Weenen (northern KwaZulu-Natal).

guinalis, *Diheteropogon amplectens*, *D. filifolius*, *Eragrostis chloromelas*, *E. plana*, *E. planiculmis*, *E. sclerantha*, *Festuca scabra*, *Heteropogon contortus*, *Hyparrhenia dregeana*, *Melinis nerviglumis*, *Microchloa caffra*, *Panicum natalense*, *Paspalum scrobiculatum*, *Setaria nigrirostris*, *Sporobolus africanus*. Herbs: *Acanthospermum australe* (d), *Argyrolobium speciosum* (d), *Eriosema kraussianum* (d), *Geranium wakkerstroomianum* (d), *Pelargonium luridum* (d), *Acalypha peduncularis*, *Chamaecrista mimosoides*, *Dicoma anomala*, *Euryops transvaalensis* subsp. *setilobus*, *Helichrysum caespititium*, *H. rugulosum*, *Hermannia depressa*, *Ipomoea crassipes*, *Pearsonia grandifolia*, *Pentanisia prunelloides* subsp. *latifolia*, *Sebaea grandis*, *Senecio inornatus*, *Thunbergia atriplicifolia*, *Zaluzianskya microsiphon*. Geophytic Herbs: *Chlorophytum haygarthii* (d), *Gladiolus aurantiacus* (d), *Asclepias aurea*, *Cyrtanthus tuckii* var. *transvaalensis*, *Gladiolus crassifolius*, *Hypoxis colchicifolia*, *H. multiceps*, *Moraea brevistyla*, *Zantedeschia rehmannii*. Succulent Herbs: *Aloe ecklonis*, *Lopholaena segmentata*. Low Shrubs: *Anthospermum rigidum* subsp. *pumilum*, *Erica oatesii*, *Hermannia geniculata*. Succulent Shrub: *Euphorbia pulvinata*.

Biogeographically Important Taxa (both Low Escarpment endemics) Succulent Herb: *Aloe modesta*. Low Shrub: *Bowkeria citrina*.

Conservation Vulnerable. Target 24%. Only about 2% statutorily conserved in the uKhahlamba Drakensberg Park as well as in the Chelmsford, Spioenkop, Moor Park, Wagendrift, Ncandu Nature Reserves. More than a quarter has already been transformed either for cultivation, plantations and urban sprawl or by building of dams (Chelmsford, Driel, Kilburn, Mtoti, Wagendrift, Windsor and Woodstock). Alien *Acacia dealbata*, *Rubus*, *Eucalyptus* and *Populus* are invasive in places. Bush encroachment is common. Erosion very low (53%), low (2%) and moderate (20%).

References Acocks (1953, 1988), Smit (1992), Smit et al. (1993a, 1995a, c), Camp (1999a).

Gs 5 Northern KwaZulu-Natal Shrubland

VT 65 Southern Tall Grassveld (68%) (Acocks 1953). Interior *Acacia caffra* Scrub and Tree Veld & *Diospyros lycioides* Scrub (Edwards 1967). LR 25 Natal Central Bushveld (60%) (Low & Rebelo 1996). BRG 11 Moist Transitional Tall Grassveld (42%), BRG 12 Moist Tall Grassveld (34%) (Camp 1999a, c).

Distribution KwaZulu-Natal Province: A widely scattered group of patches. Embedded within Sub-Escarpment Grassland units of Gs 4, Gs 6 and Gs 7, from Ladysmith in the west to Vryheid in the northeast. Large portions of this unit are found in the surrounds of Newcastle. Altitude 1 100–1 540 m.

Vegetation & Landscape Features Small dolerite koppies and steeper slopes of ridges with sparse grass cover and typical occurrence of scattered shrubland pockets (and locally also thickets). *Acacia caffra*, *A. natalitia*, *Clerodendrum glabrum*, *Diospyros lycioides*, *Rhus pyroides*, *R. pentheri*, *Scutia myrtina* etc. are the most prominent shrubs and small trees.

Geology & Soils Karoo Sequence sediments underlie this area: Madzaringwe Formation shale and sandstones are found in the east and Adelaide Subgroup and Volksrust Formation mudrocks occur in the west. The most significant feature is the intrusive dolerite dykes and sills which give rise to heavy clayey soils. Fa and Fb land types have an equal importance, followed by Ea.

Climate Summer rainfall, with MAP 800 mm. Overall MAT of 16.1°C indicates a transition between cool- and warm-temperate climates. Frost fairly infrequent. See also climate diagram for Gs 5 Northern KwaZulu-Natal Shrubland (Figure 8.61).

Important Taxa Small Trees: *Acacia caffra* (d), *A. natalitia* (d), *A. sieberiana* var. *woodii*, *Cussonia paniculata*, *Euclea crispa* subsp. *crispa*, *Heteromorpha arborescens* var. *abyssinica*, *Hippobromus pauciflorus*, *Scutia myrtina*, *Ziziphus mucronata*. Tall Shrubs: *Diospyros lycioides* subsp. *lycioides* (d), *Rhus rehmanniana* var. *rehmanniana* (d), *Acokanthera oppositifolia*, *Asparagus setaceus*, *Canthium mundianum*, *Cephalanthus natalensis*, *Clerodendrum glabrum*, *Diospyros whyteana*, *Euclea natalensis* subsp. *angustifolia*, *Leonotis leonurus*, *Lippia javanica*, *Pavetta gardeniifolia* var. *gardeniifolia*, *Rhus dentata*, *R. lucida*, *R. pentheri*, *R. pyroides*, *Scolopia zeyheri*. Woody Climbers: *Clematis brachiata*, *Dalbergia obovata*, *Dioscorea sylvatica*, *Jasminum breviflorum*, *Rhoicissus tridentata*. Succulent Woody Climber: *Sarcostemma viminale*. Low Shrubs: *Barleria obtusa* (d), *Anthospermum rigidum* subsp. *pumilum*, *Artemisia afra*, *Chaetacanthus burchellii*, *Euryops pedunculatus, Grewia hispida*, *Phyllanthus glaucophyllus*, *Pygmaeothamnus chamaedendrum*. Succulent Shrub: *Euphorbia clavarioides* var. *clavarioides*. Graminoids: *Cymbopogon caesius* (d), *Eragrostis racemosa* (d), *Hyparrhenia hirta* (d), *Themeda triandra* (d), *Bothriochloa insculpta*, *Cymbopogon nardus*, *Eragrostis curvula*, *E. plana*, *Hyparrhenia dregeana*, *Setaria sphacelata*. Herbs: *Acalypha caperonioides*, *A. punctata*, *Aster bakerianus*, *Commelina africana*, *Conyza obscura*, *Corchorus confusus*, *Crabbea angustifolia*, *Dicoma anomala*, *Eriosema cordatum*, *Helichrysum rugulosum*, *Ipomoea oblongata*, *Monsonia angustifolia*, *Selago densiflora*, *Stachys natalensis*. Geophytic Herbs: *Cheilanthes hirta*, *C. quadripinnata*, *Hypoxis rigidula* var. *pilosissima*, *Ledebouria ovatifolia*, *Oxalis obliquifolia*, *Pellaea calomelanos*, *Raphionacme hirsuta*. Succulent Herbs: *Aloe maculata*, *Crassula alba*.

Biogeographically Important Taxon (endemic to northern KwaZulu-Natal) Herb: *Cissus cussonioides*.

Endemic Taxon Tall Shrub: *Calpurnia woodii*.

Conservation Least threatened. Target 23%. Less than 1% statutorily conserved in the Spioenkop Nature Reserve. About 3% transformed by cultivation. Erosion very low (35%), moderate (29%), low (22%) and high (10%).

Remark This vegetation is floristically similar to sourveld of the Highveld region (e.g. Suikerbosrand) on the one hand and to montane shrublands of the Drakensberg area on the other.

References Smit et al. (1995b), Eckhardt et al. (1997), Eckhardt (1998), Robesson (1998).

Gs 6 KwaZulu-Natal Highland Thornveld

VT 65 Southern Tall Grassveld (57%) (Acocks 1953). *Acacia sieberiana* Tree Veld (Edwards 1967). LR 25 Natal Central Bushveld (72%) (Low & Rebelo 1996). BRG 13 Dry Tall Grassveld (89%) (Camp 1999c).

Distribution KwaZulu-Natal Province: A series of several patches in the central-northern regions of KwaZulu-Natal, where it occurs on both dry valleys and moist upland. The most extensive area is found in the region from Ladysmith, Winterton, Estcourt and Colenso, between Mooi River and Greytown, between Pomeroy and Babanago, and further north in a triangle between Vryheid, Paulpietersburg and Louwsburg as well as a large patch around Newcastle. Altitude 920–1 440 m.

Vegetation & Landscape Features Hilly, undulating landscapes and broad valleys supporting tall tussock grassland usually dominated by *Hyparrhenia hirta*, with occasional savannoid woodlands with scattered *Acacia sieberiana* var. *woodii* and in small pockets also with *A. karroo* and *A. nilotica*.

Geology & Soils A variety of Karoo Supergroup rocks occur in the area, including the Dwyka, Ecca and Beaufort Groups and marginally also Jurassic dolerite intrusions. Yellow-brown soils over plinthic subsoil and shallow duplex soils are common. Red and black heavy soils are derived from dolerites and show high resistance to erosion. The unit falls within various land types, including Ca, Fb, Fa, Db and Bb.

Climate Summer rainfall. MAP about 750 mm (79 rain days per year; Camp 1999c). The midwinter months of June and July have 2.6 rain days on average. Much of the summer precipitation comes in form of thunderstorms (63 and 56 thunderstorm days per year for Ladysmith and Estcourt, respectively). Mist is uncommon (14 days of mist per year for both Ladysmith and Estcourt). MAT 15.6–19.0°C (overall average 16.5°C). Summers are warm to hot, winters are cool. There are 15 frost days per year. The mean annual evaporation recorded at Estcourt is 1 725 mm, while the range for the entire vegetation unit is 1 706–1 918 mm (Camp 1999c), the overall average 1 830 mm. See also climate diagram for Gs 6 KwaZulu-Natal Highland Thornveld (Figure 8.61).

Important Taxa Small Trees: *Acacia sieberiana* var. *woodii* (d), *A. natalitia*, *A. nilotica*, *Cussonia spicata*, *Ziziphus mucronata*. Tall Shrub: *Dichrostachys cinerea*. Low Shrubs: *Barleria obtusa* (d), *Anthospermum rigidum* subsp. *pumilum*, *Chaetacanthus setiger*, *Gymnosporia heterophylla*. Semiparasitic Shrub: *Thesium costatum*. Graminoids: *Abildgaardia ovata* (d), *Andropogon eucomus* (d), *Aristida bipartita* (d), *A. congesta* (d), *Chloris virgata* (d), *Cynodon dactylon* (d), *Elionurus muticus* (d), *Eragrostis capensis* (d), *E. chloromelas* (d), *E. plana* (d), *E. racemosa* (d), *E. superba* (d), *Heteropogon contortus* (d), *Hyparrhenia hirta* (d), *Setaria sphacelata* (d), *Themeda triandra* (d), *Tristachya leucothrix* (d), *Andropogon appendiculatus*, *Brachiaria serrata*, *Cymbopogon caesius*, *C. marginatus*, *C. pospischilii*, *Cyperus obtusiflorus* var. *obtusiflorus*, *Digitaria monodactyla*, *D. tricholaenoides*, *Diheteropogon amplectens*, *Eragrostis curvula*, *E. gummiflua*, *E. patentissima*, *Harpochloa falx*, *Microchloa caffra*, *Panicum natalense*, *Setaria nigrirostris*, *Sporobolus africanus*, *S. pyramidalis*. Herbs: *Hermannia depressa* (d), *Becium filamentosum*, *Chamaecrista mimosoides*, *Euryops transvaalensis* subsp. *setilobus*, *Haplocarpha scaposa*, *Helichrysum rugulosum*. Herbaceous Climber: *Rhynchosia totta*. Geophytic Herb: *Haemanthus montanus*. Succulent Herbs: *Aloe dominella*, *A. greenii*, *Orbea woodii*.

Endemic Taxa Low Shrub: *Barleria greenii*. Succulent Shrub: *Aloe gerstneri*. Succulent Herb: *Aloe inconspicua*.

Conservation Least threatened. Target 23%. Only about 2% statutorily conserved in the Spioenkop, Weenen, Ntinini, Wagendrift, Moor Park and Tugela Drift Nature Reserves. More than 16% has been transformed for cultivation and by urban sprawl as well as by building of dams (Craigie Burn, Spioenkop, Wagendrift and Windsor). Alien *Opuntia*, *Eucalyptus*, *Populus*, *Acacia* and *Melia* are becoming invasive in places, but probably the greatest threat to the remaining natural areas of this unit is bush encroachment. Erosion very low (34%), low (29%), moderate (2%) and high (12%).

Remarks The presence of sparse woodlands with *Acacia* are considered a management problem and ascribed to 'bush encroachment' (Edwards 1967, Camp 1999c). One may, however, argue that the region of this vegetation unit has always been a natural mosaic of open tall grassland and sparse woodland (with virtually the same species composition as the neighbouring grassland), with progressive encroachment of woody elements into grassland, especially in heavily disturbed areas.

References Acocks (1953, 1988), Edwards (1967), Adams (1996), Morris & Tainton (1996), Roos & Allsopp (1997), Robesson (1998), Camp (1999c), Scott-Shaw (1999).

Gs 7 Income Sandy Grassland

VT 66 Natal Sour Sandveld (68%) (Acocks 1953). LR 25 Natal Central Bushveld (85%) (Low & Rebelo 1996). BRG 14 Sour Sandveld (76%) (Camp 1999c).

Distribution KwaZulu-Natal Province: In a large triangle between Newcastle, Vryheid and Dundee and larger polygon in the Wasbank area in northern KwaZulu-Natal. Altitude 880–1 340 m (mainly 1 120–1 240 m).

Vegetation & Landscape Features Very flat extensive areas with generally shallow, poorly drained, sandy soils supporting low, tussock-dominated sourveld forming a mosaic with wooded grasslands (with *Acacia sieberiana* var. *woodii*) and on well-drained sites with the trees *A. karroo*, *A. nilotica*, *A. caffra* and *Diospyros lycioides*. On disturbed sites *A. sieberiana* var. *woodii* can form sparse woodlands. *Aristida congesta*, *Cynodon dactylon* and *Microchloa caffra* are common on shallow soils (Camp 1999c).

Geology & Soils Sandstones and shale of the Madzaringwe Formation (Ecca Group of Karoo Supergroup) supporting poorly drained sandy soils, mostly of the Glenrosa form. Most important land types Ca, Bb and Fb.

Climate Region of summer rainfall, with most precipitation occurring between October and March (overall MAP 750 mm; range 650–800 mm), much of which falls as thundershowers often accompanied by hail. MAT is just below 17°C, and mean annual evaporation 1 845 mm. Frost moderate (Camp 1999c). See also climate diagram for Gs 7 Income Sandy Grassland (Figure 8.61).

Important Taxa Graminoids: *Andropogon appendiculatus* (d), *Brachiaria serrata* (d), *Cynodon dactylon* (d), *Digitaria monodactyla* (d), *D. tricholaenoides* (d), *Eragrostis curvula* (d), *E. gummiflua* (d), *E. plana* (d), *E. racemosa* (d), *Heteropogon contortus* (d), *Hyparrhenia hirta* (d), *Loudetia simplex* (d), *Paspalum scrobiculatum* (d), *Tristachya leucothrix* (d), *Alloteropsis semialata* subsp. *eckloniana*, *Andropogon eucomus*, *A. schirensis*, *Aristida congesta*, *A. junciformis* subsp. *galpinii*, *Cymbopogon caesius*, *Diheteropogon amplectens*, *D. filifolius*, *Elionurus muticus*, *Eragrostis capensis*, *E. chloromelas*, *E. planiculmis*, *E. scleranthe*, *Harpochloa falx*, *Melinis repens* subsp. *repens*, *Microchloa caffra*, *Monocymbium ceresiiforme*, *Panicum natalense*, *Perotis patens*, *Pogonarthria squarrosa*, *Setaria nigrirostris*, *Sporobolus africanus*, *Stiburus conrathii*, *Themeda triandra*, *Trichoneura grandiglumis*. Herbs: *Helichrysum rugulosum* (d), *Berkheya onopordifolia* var. *glabra*, *B. setifera*, *Chamaecrista mimosoides*, *Dicoma anomala*, *Euryops transvaalensis* subsp. *setilobus*, *Helichrysum caespititium*, *H. cephaloideum*, *H. simillimum*, *Hermannia depressa*, *H. transvaalensis*, *Kohautia amatymbica*, *K. virgata*, *Macledium zeyheri* subsp. *argyrophylum*, *Pentanisia prunelloides* subsp. *latifolia*, *Senecio coronatus*, *Zornia capensis*. Herbaceous Climber: *Rhynchosia totta*. Geophytic Herb: *Hypoxis rigidula* var. *pilosissima*. Low Shrubs: *Anthospermum rigidum* subsp. *pumilum*, *Stoebe plumosa*.

Conservation Vulnerable. Target 23%. None conserved in statutory conservation areas. Some 27% has been transformed for cultivation, plantations and by urban sprawl. Small portion of the area has been lost to the building of dams (Klipfontein, Mvunyane). No serious invasions of aliens have been observed (probably due to low nutrient status of soils). Erosion moderate (38%), high (30%) and low (15%).

Remarks The differences between this unit and the Gs 13 Mabela Sandy Grassland (in East Griqualand), lie especially in some climatic and vegetation patterns. Cedarville (in Gs 13 Mabela Sandy Grassland) is much colder (MAT 14°C), shows lower transpiration, has higher incidence of frost and hence lacks indigenous trees.

References Acocks (1953, 1988), Eckhardt et al. (1996a, b), Eckhardt (1998), Camp (1999c).

Gs 8 Mooi River Highland Grassland

VT 44 Highland Sourveld and Dohne Sourveld (77%) (Acocks 1953). LR 42 Moist Upland Grassland (48%), LR 43 North-eastern Mountain Grassland (27%) (Low & Rebelo 1996). BRG 9 Dry Highland Sourveld (99%) (Camp 1999b).

Distribution KwaZulu-Natal Province: Centre of occurrence in the Mooi River Basin, several scattered large patches near Underberg and Greytown, and on the Helpmekaar Plateau southeast of Dundee. Altitude 1 340–1 620 m.

Vegetation & Landscape Features Mainly rolling and partly broken landscape, covered in grassland dominated by short bunch grasses. *Heteropogon contortus*, *Themeda triandra* and *Tristachya leucothrix* are dominant in well-managed veld.

Geology & Soils A mosaic of generally shallow and poorly drained soils derived from sedimentary rocks, mostly of the Adelaide Subgroup (Beaufort Group) of the Karoo Sequence. Deep well-drained apedal soils of the intrusive igneous rocks of the Karoo Dolerite Suite also occur. Almost half of the area is classified as Ac land type, followed by Bb and to lesser extent also Fa.

Climate The region has a MAP of 785 mm, falling mostly in summer. Mist and snow are not frequent. Overall MAT is slightly higher than 14°C. Light, but relatively frequent (30 days per year) frosts may occur for six months in the year (Camp 1999b). See also climate diagram for Gs 8 Mooi River Highland Grassland (Figure 8.61).

Important Taxa Graminoids: *Diheteropogon filifolius* (d), *Eragrostis curvula* (d), *E. plana* (d), *E. racemosa* (d), *Heteropogon contortus* (d), *Microchloa caffra* (d), *Monocymbium ceresiiforme* (d), *Panicum ecklonii* (d), *P. gilvum* (d), *Sporobolus africanus* (d), *Themeda triandra* (d), *Tristachya leucothrix* (d), *Alloteropsis semialata* subsp. *eckloniana*, *Andropogon schirensis*, *Aristida junciformis* subsp. *galpinii*, *Brachiaria serrata*, *Cynodon dactylon*, *Digitaria monodactyla*, *D. tricholaenoides*, *Diheteropogon amplectens*, *Eragrostis capensis*, *E. chloromelas*, *Harpochloa falx*, *Pycreus flavescens*, *P. niger* subsp. *niger*, *Setaria nigrirostris*. Herbs: *Acalypha depressinerva*, *Becium filamentosum*, *Berkheya setifera*, *Conyza pinnata*, *Didymodoxa caffra*, *Geranium ornithopodioides*, *Pentanisia prunelloides* subsp. *latifolia*, *Plectranthus laxiflorus*, *Salvia repens*, *Schistostephium crataegifolium*, *Sebaea grandis*, *Senecio gregatus*, *Vernonia natalensis*. Herbaceous Climbers: *Rhynchosia caribaea* (d), *R. totta*. Geophytic Herb: *Oxalis purpurea*. Low Shrubs: *Anthospermum rigidum* subsp. *pumilum*, *Senecio burchellii*.

Conservation Vulnerable. Target 23%. Only a tiny part statutorily conserved in the Swamp Nature Reserve. Almost a quarter of the area has been transformed for cultivation (maize, beef and dairy farming) or plantations. Alien woody plants such as *Acacia dealbata*, *Rubus* species, *Melia azedarach*, *Sesbania punicea*, *Populus x canescens*, *P. alba* and *Eucalyptus* species are invaders in some places. Erosion is very low (70%) and low (25%).

Remark This unit is a dry version of Gs 10 Drakensberg Foothill Moist Grassland, generally occurring in an adjacent rainshadow area.

References Acocks (1953, 1988), Camp (1999b).

Gs 9 Midlands Mistbelt Grassland

VT 45 Ngongoni Veld of Natal Mist-belt (38%), VT 44 Highland Sourveld and Dohne Sourveld (33%) (Acocks 1953). LR 42 Moist Upland Grassland (41%), LR 47 Short Mistbelt Grassland (37%) (Low & Rebelo 1996). BRG 5 Moist Midlands Mistbelt, BRG 6 Dry Midlands Mistbelt (Camp 1999a).

Distribution KwaZulu-Natal and Eastern Cape Provinces: KwaZulu-Natal Midlands—scattered in broad belt in the form of several major patches including Melmoth-Babanango area, Kranskop and Greytown, Howick Lions River, Karkloof, Balgowan, Cedara, Edendale, Hilton, Richmond, the Ixopo-Highflats area, Mount Malowe in the Umzimkhulu enclave of the Eastern Cape Province and the Harding-Weza area. The southwesternmost section in the Eastern Cape Province falls in the Bulembu, Gxwaleni, Longweni and Flagstaff areas. Altitude 760–1 400 m.

Vegetation & Landscape Features Hilly and rolling landscape mainly associated with a discontinuous east-facing scarp formed by dolerite intrusions (south of the Thukela River). Dominated by forb-rich, tall, sour *Themeda triandra* grasslands transformed by the invasion of native 'Ngongoni grass (*Aristida junciformis* subsp. *junciformis*). Only a few patches of the original species-rich grasslands remain.

Geology & Soils Apedal and plinthic soil forms derived mostly from Ecca Group (Karoo Supergroup) shale and minor sandstone and less importantly from

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Figure 8.65 Gs 8 Mooi River Highland Grassland: Patch of Sub-Escarpment Grassland near Mooi River (western KwaZulu-Natal) dominated by grasses such as *Themeda triandra, Harpochloa falx, Tristachya leucothrix* and *Hyparrhenia hirta* supporting a rich herb flora.

Jurassic dolerite dykes and sills. Dominant land type Ac, followed by Fa.

Climate Summer rainfall, with MAP of 915 mm, range 730–1 280 mm. Heavy and frequent occurrence of mist provides significant amounts of additional moisture (Cedara near Pietermaritzburg has 46 misty days per year). Some of the rain is in the form of cold frontal activity, mainly in winter, spring and early summer. Thunderstorms are common in summer and autumn (Cedara: 60 days of thunderstorms per year). Mean annual evaporation 1 463–1 797 mm (Camp 1999a). MAT 15.8°C, absolute minimum temperature was recorded in this region in June (–10.8°C). Frosts are generally moderate, but occasional severe frost may also occur. Further climatic conditions include short-term drought spells, hail and hot northwestern berg winds occurring particularly in spring and early summer. See also climate diagram for Gs 9 Midlands Mistbelt Grassland (Figure 8.61).

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Figure 8.66 Gs 9 Midlands Mistbelt Grassland: Grasslands in the Lions River region near Howick (KwaZulu-Natal) with common herbs such as *Senecio bupleuroides*, *Helichrysum pallidum* and *Alepidea longifolia*.

Important Taxa Graminoids: *Andropogon appendiculatus* (d), *Aristida junciformis* subsp. *galpinii* (d), *Diheteropogon filifolius* (d), *Eragrostis plana* (d), *Hyparrhenia hirta* (d), *Sporobolus africanus* (d), *Themeda triandra* (d), *Tristachya leucothrix* (d), *Alloteropsis semialata* subsp. *eckloniana*, *Andropogon schirensis*, *Brachiaria serrata*, *Cymbopogon caesius*, *C. nardus*, *Digitaria diagonalis*, *D. tricholaenoides*, *Diheteropogon amplectens*, *Elionurus muticus*, *Eragrostis capensis*, *E. curvula*, *E. racemosa*, *Eulalia villosa*, *Harpochloa falx*, *Heteropogon contortus*, *Loudetia simplex*, *Microchloa caffra*, *Monocymbium ceresiiforme*, *Panicum aequinerve*, *P. ecklonii*, *P. natalense*, *Paspalum dilatatum*, *P. scrobiculatum*, *P. urvillei*, *Setaria nigrirostris*, *S. sphacelata*, *Sporobolus centrifugus*, *Trachypogon spicatus*. Herbs: *Acalypha glandulifolia*, *Acanthospermum australe*, *Berkheya rhapontica* subsp. *aristosa*, *B. setifera*, *Commelina africana*, *Conyza pinnata*, *Eriosema salignum*, *Helichrysum cephaloideum*, *H. simillimum*, *Indigastrum fastigiatum*, *Kohautia amatymbica*, *Nidorella auriculata*, *Pentanisia prunelloides* subsp. *latifolia*, *Sebaea sedoides* var. *schoenlandii*, *Spermacoce natalensis*, *Thunbergia atriplicifolia*, *Vernonia dregeana*, *V. natalensis*, *Wahlenbergia undulata*. Herbaceous Climber: *Vigna nervosa*. Geophytic Herbs: *Pteridium aquilinum* (d), *Corycium nigrescens*, *Drimia macrocentra*, *Eriospermum ornithogaloides*, *Gladiolus ecklonii*, *Habenaria dives*, *H. dregeana*, *Hypoxis multiceps*, *H. rigidula* var. *pilosissima*, *Rhodohypoxis baurii* var. *baurii*, *R. baurii* var. *platypetala*, *Satyrium longicauda*. Low Shrubs: *Helichrysum sutherlandii*, *Leonotis ocymifolia*, *Otholobium caffrum*.

Biogeographically Important Taxa (both Southern distribution limit) Herb: *Anisopappus smutsii*. Succulent Herb: *Aloe kniphofioides*.

Endemic Taxa Herbs: *Acalypha entumenica*, *Selago longiflora*. Geophytic Herbs: *Asclepias woodii*, *Albuca xanthocodon*, *Dierama luteoalbidum*, *Kniphofia latifolia*, *Pachycarpus rostratus*, *Watsonia canaliculata*. Low Shrubs: *Helichrysum citricephalum*, *Syncolostemon latidens*.

Conservation Endangered (one of the most threatened vegetation types of KwaZulu-Natal). Target 23%. Only a small fraction (about 0.5%) statutorily conserved in number of reserves such as Ngeli, Impendle, Blinkwater, Qudeni, Doreen Clark, Karkloof and Queen Elizabeth Park—still heavily underrepresented in conservation plans (see also analysis of 'Natal Mistbelt' by Scott-Shaw et al. (1996). More than half already transformed for plantations, cultivated land or by urban sprawl. Uncontrolled fires and poorly regulated grazing by livestock add to threats to this unique grassland. Some aliens (including *Solanum mauritianum*, species of *Rubus*, *Acacia*, *Pinus* and *Eucalyptus*) are of concern in places. Erosion is very low (68%) and low (24%).

Remark 1 As pointed out by Camp (1999a), the difference between BRG 5 (Moist Midlands Mistbelt) and BRG 6 (Dry Midlands Mistbelt) lies basically in precipitation: the latter occurring in regions receiving between 738–825 mm, while the former receives more than 800 mm on average per year as a rule. Both BRGs are considered by Camp (1999a) as different moisture phases of the same vegetation type. The consideration of 800 mm is very informative from the point of view of moisture status of soils and might also be of agricultural importance. However, the lack of striking differences in vegetation patterns does not justify separation of the BRGs as distinct vegetation units. Extensive patches of the Eastern Mistbelt Forests in KwaZulu-Natal and Transkei Mistbelt Forests in the Eastern Cape (for the concepts see Von Maltitz et al. 2003) are embedded within the region of the Midlands Mistbelt.

Remark 2 The Mistbelt of KwaZulu-Natal is an important, although still not a formally recognised, centre of endemism (see Van Wyk & Smith 2001).

References Acocks (1953, 1988), Colvin (1984), Scott-Shaw et al. (1996), Camp (1999a), Scott-Shaw (1999).

Gs 10 Drakensberg Foothill Moist Grassland

Mountain Tussock Veld (Bews 1917). VT 44 Highland Sourveld and Dohne Sourveld (90%) (Acocks 1953). LR 42 Moist Upland Grassland (82%) (Low & Rebelo 1996).

Distribution KwaZulu-Natal and Eastern Cape Provinces: Broad arc of Drakensberg piedmonts covering the surrounds of Bergville in the north, Nottingham Road, Impendle, Bulwer in the east, and Kokstad, Mount Currie, Underberg (KZN) and the surrounds of Mt Fletcher, Ugie, Maclear and Elliot (Eastern Cape) in the southwest. Altitude 880–1 860 m.

Vegetation & Landscape Features Moderately rolling and mountainous, much incised by river gorges of drier vegetation types and by forest, and covered in forb-rich grassland dominated by short bunch grasses including *Themeda triandra* and *Tristachya leucothrix*.

Geology & Soils Geology is dominated by mudstones and sandstones of the Tarkastad Subgroup and the Molteno Formation (Karoo Supergroup) as well as intrusive dolerites of Jurassic age. The dominant soils on the sedimentary parent material are well drained, with a depth of more than 800 mm and clay content from 15–55%, representing soil forms such as Hutton, Clovelly, Griffin and Oatsdale. On the volcanic parent material (dolerite) the soils are represented by forms such as Balmoral, Shortlands and Vimy. Most common land types Ac and Fa.

Climate Summer rainfall, with MAP almost 890 mm. MAT of 14.6°C and 26 frost days per year are indicative of a cooler, submontane form of warm-temperate climate. See also the climate diagram Gs 10 Drakensberg Foothill Moist Grassland (Figure 8.61).

Important Taxa Graminoids: *Diheteropogon filifolius* (d), *Elionurus muticus* (d), *Eragrostis capensis* (d), *E. chloromelas* (d), *E. curvula* (d), *E. plana* (d), *E. racemosa* (d), *Heteropogon contortus* (d), *Microchloa caffra* (d), *Monocymbium ceresiiforme* (d), *Panicum natalense* (d), *Rendlia altera* (d), *Sporobolus africanus* (d), *Themeda triandra* (d), *Trachypogon spicatus* (d), *Tristachya leucothrix* (d), *Agrostis lachnantha*, *Alloteropsis semialata* subsp. *eckloniana*, *Aristida junciformis* subsp. *galpinii*, *Brachiaria serrata*, *Digitaria tricholaenoides*, *Harpochloa falx*, *Hyparrhenia hirta*, *Panicum ecklonii*, *Paspalum dilatatum*. Herbs: *Helichrysum simillimum* (d), *Senecio retrorsus* (d), *Acalypha depressinerva*, *Ajuga ophrydis*, *Berkheya rhapontica* subsp. *aristosa*, *Conyza pinnata*, *Dicoma anomala*, *Euryops laxus*, *Haplocarpha scaposa*, *Helichrysum chionosphaerum*, *H. cooperi*, *H. herbaceum*, *H. nudifolium* var. *pilosellum*, *H. subglomeratum*, *H. umbraculigerum*, *Hesperantha ingeliensis*, *Kohautia amatymbica*, *Mohria caffrorum*, *Pentanisia prunelloides* subsp. *latifolia*, *Schistostephium crataegifolium*, *Sebaea sedoides* var. *schoenlandii*, *S. sedoides* var. *sedoides*, *Senecio asperulus*, *Vernonia natalensis*, *Wahlenbergia undulata*. Herbaceous Climber: *Rhynchosia totta*. Geophytic Herbs: *Oxalis depressa* (d), *Cheilanthes deltoidea*, *C. hirta*, *Chlorophytum acutum*, *Disperis renibractea*, *Habenaria dregeana*, *H. lithophila*, *Haemanthus humilis* subsp. *hirsutus*, *Hesperantha coccinea*, *Hypoxis rigidula* var. *pilosissima*, *Ledebouria sandersonii*, *Moraea modesta*, *Nerine bowdenii*, *Oxalis corniculata*, *Rhodohypoxis baurii* var. *platypetala*, *Watsonia pillansii*, *Xysmalobium tysonianum*, *Zantedeschia albomaculata* subsp. *albomaculata*. Small Trees: *Protea roupelliae* subsp. *roupelliae* (d), *Encephalartos ghellinckii*. Low Shrubs: *Anthospermum rigidum* subsp. *pumilum*, *Chrysocoma ciliata*, *Felicia filifolia* subsp. *filifolia*, *Gnidia kraussiana*, *Helichrysum odoratissimum*, *H. sutherlandii*, *Rhus discolor*, *Senecio burchellii*.

Biogeographically Important Taxa ([D]Drakensberg endemic, [Dg]Drakensberg endemic extending to Griqualand East) Geophytic Herb: *Schizochilus bulbinella*[Dg]. Graminoid: *Schoenoxiphium burttii*[D].

Endemic Taxa Herbs: *Alchemilla incurvata*, *Argyrolobium sericosemium*, *Diascia esterhuyseniae*, *Stachys rivularis*. Geophytic Herbs: *Brachystelma molaventi*, *Dioscorea brownii*, *Ornithogalum baurii*. Succulent Shrub: *Delosperma wiunii*.

Conservation Least threatened. Target 23%. Only 2–3% statutorily conserved in the uKhahlamba Drakensberg Park, Ntsikeni Wildlife Reserve as well as in the Karkloof, Mount Currie, Coleford, Fort Nottingham, Impendle, Ngeli, and Umgeni Vlei Nature Reserves. Almost 20% already transformed for cultivation, plantations and by urban sprawl. Alien woody species of *Rubus* and *Acacia dealbata* and *Solanum mauritianum* may become invasive in places. Erosion is very low (49%), low (28%) and moderate (17%).

Remarks Due to the considerable concentration of local endemics as well as Drakensberg endemics, this unit might be reclassified as a Gd grassland unit after detailed analysis and its area included within the realm of the Drakensberg Alpine CE.

References Bews (1917), Acocks (1953, 1988), Killick (1963), Hurt et al. (1993), Camp (1999b), KZN DAEA (2003).

Gs 11 Southern KwaZulu-Natal Moist Grassland

VT 65 Southern Tall Grassveld (48%), VT 44 Highland Sourveld and Dohne Sourveld (35%) (Acocks 1953). LR 43 North-eastern Mountain Grassland (44%), LR 42 Moist Upland Grassland (36%) (Low & Rebelo 1996). BRG 11 Moist Transitional Tall Grassveld (77%) (Camp 1999a, c).

Distribution KwaZulu-Natal and Eastern Cape Provinces: Interior valley basins at Creighton, Malenge and Centocow in the south and the upper Mkomazi River and Howick in the north. Altitude 880–1 480 m.

Vegetation & Landscape Features Gently sloping valley bottoms of tall mixed veld dominated by *Hyparrhenia hirta* and sparsely scattered *Acacia sieberiana*. *Themeda triandra* is the dominant grass on veld that has been well managed and many species of Gs 10 Drakensberg Foothill Moist Grassland are well represented and include *Diheteropogon filifolius*, *Harpochloa falx* and *Trachypogon spicatus*. Overgrazed areas become dominated by 'mtshiki' species such as *Eragrostis curvula*, *E. plana*, *Sporobolus africanus* and *S. pyramidalis*. Selective overgrazing causes certain wiregrass species (*Elionurus muticus* and *Aristida junciformis*) to become abundant (Camp 1999a, c).

Geology & Soils Karoo Supergroup mudstones dominate this area, those of the Volksrust Formation occurring to the south and those of the Adelaide Subgroup to the north. Jurassic dolerite dykes are also present. The dominant soils are mottled and poorly drained, with a depth of 300–500 mm; the clay content ranges from 15–35%, representing soil forms such as Wasbank, Wesselnek, Longlands and Cartref, and Oatsdale on well drained soils. Half of the area is classified as Ac land type, with Fa and Ab of minor occurrence.

Climate Summer rainfall, with MAP of 920 mm. Cooler form of warm-temperate climate (MAT 15.6°C; 15 frost days a year). See also climate diagram for Gs 11 Southern KwaZulu-Natal Moist Grassland (Figure 8.61).

Important Taxa Graminoids: *Alloteropsis semialata* subsp. *eckloniana* (d), *Andropogon appendiculatus* (d), *A. schirensis* (d), *Cynodon incompletus* (d), *Digitaria ternata* (d), *Eragrostis chloromelas* (d), *E. curvula* (d), *E. plana* (d), *Hyparrhenia hirta* (d), *Microchloa caffra* (d), *Paspalum dilatatum* (d), *Setaria nigrirostris* (d), *Sporobolus africanus* (d), *Tristachya leucothrix* (d), *Brachiaria serrata*, *Cyperus albostriatus*, *Digitaria sanguinalis*, *D. tricholaenoides*, *Elionurus muticus*, *Heteropogon contortus*, *Panicum aequinerve*, *Pycreus rehmannianus*, *Setaria sphacelata*, *Themeda triandra*, *Trachypogon spicatus*. Herbs: *Acrotome inflata* (d), *Conyza pinnata* (d), *Acanthospermum australe*, *Ajuga ophrydis*, *Berkheya setifera*, *Chamaecrista mimosoides*, *Cynoglossum lanceolatum*, *Eriosema kraussianum*, *Helichrysum nudifolium* var. *nudifolium*, *Lobelia erinus*, *Spermacoce natalensis*, *Vernonia natalensis*. Herbaceous Climber: *Rhynchosia totta*. Geophytic Herbs: *Oxalis corniculata* (d), *O. smithiana* (d),

Pteridium aquilinum (d), *Cheilanthes bergiana*, *Zantedeschia albomaculata* subsp. *albomaculata*. Low Shrubs: *Asparagus virgatus*, *Erica caffrorum* var. *caffrorum*, *Rubus cuneifolius*.

Endemic Taxon Low Shrub: *Erica psittacina*.

Conservation Vulnerable. Target 23%. About 4% statutorily conserved in the Impendle, Midmar, Igxalingenwa and Ingelabantwana Nature Reserves as well as in the Soada Forest Nature Reserve and in the uKhahlamba Drakensberg Park. More than one third already transformed for cultivation, plantations, by urban sprawl and building of dams (Midmar). Several woody aliens (*Solanum mauritianum*, *Arundo donax*, *Eucalyptus* species, *Melia azedarach*, *Sesbania punicea*, *Populus alba*) occur in these grasslands, but their impact is only of local importance. Erosion is very low (47%) and low (46%).

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Figure 8.67 Gs 12 East Griqualand Grassland: Over-grazed, species-poor grasslands on sandy soils on slopes prone to erosion near Mount Frere (northeastern Eastern Cape). The grasslands at higher altitudes belong to Gs 10 Drakensberg Foothill Moist Grassland–a transitional type between Sub-Escarpment and Drakensberg Grasslands.

References Acocks (1953, 1988), Camp (1999a, c), KZN DAEA (2003).

Gs 12 East Griqualand Grassland

VT 44 Highland Sourveld and Dohne Sourveld (58%) (Acocks 1953). LR 42 Moist Upland Grassland (90%) (Low & Rebelo 1996).

Distribution KwaZulu-Natal and Eastern Cape Provinces: Major portion of this unit covers most of East Griqualand (with Kokstad and Matatiele as centres). Altitude 920–1 740 m.

Vegetation & Landscape Features Hilly country with slopes covered by grassland in places, with patches of bush clumps with *Leucosidea sericea* (only wet sites) or *Diospyros lycioides*, *Acacia karroo* and *Ziziphus mucronata* in low-lying and very dry sites.

Geology & Soils Mudstone and sandstone of the Beaufort Group of the Karoo Sequence predominate, but sedimentary rocks of the Molteno, Elliot and Clarens Formations are also present. The dominant soils on the sedimentary parent material are well drained, with a depth of 500–800 mm and clay content from 15–55%. The soils are of Hutton, Clovelly, Oatsdale forms on sediments and Shortlands on dolerite. Most common land types Fa and Ac.

Climate The region has mostly summer rainfall, with MAP of 780, mm ranging from 620–816 mm. Kokstad records 88 rain days in a year and three of those occur in the midwinter (June–July). Both mist and snow occur less frequently than in Gd 4 Southern Drakensberg Highland Grassland (Kokstad 26 misty days per year) and much of the rain comes in the form of thunderstorms (Kokstad 45 days). MAT 12.9–15.6°C (overall MAT 14.7°C). Moderately severe frosts occur 30 days in a year. Mean annual evaporation 1 457–1 723 mm (Camp 1999b). See also climate diagram for Gs 12 East Griqualand Grassland (Figure 8.61).

Important Taxa Graminoids: *Alloteropsis semialata* subsp. *eckloniana* (d), *Aristida congesta* (d), *A. junciformis* subsp. *galpinii* (d), *Brachiaria serrata* (d), *Digitaria tricholaenoides* (d), *Elionurus muticus* (d), *Eragrostis chloromelas* (d), *E. plana* (d), *E. racemosa* (d), *Harpochloa falx* (d), *Heteropogon contortus* (d), *Hyparrhenia hirta* (d), *Melinis nerviglumis* (d), *Microchloa caffra* (d), *Paspalum dilatatum* (d), *Sporobolus africanus* (d), *Themeda triandra* (d), *Tristachya leucothrix* (d), *Abildgaardia ovata*, *Andropogon appendiculatus*, *Cynodon incompletus*, *Cyperus obtusiflorus* var. *obtusiflorus*, *Digitaria ternata*, *Eragrostis capensis*, *Eulalia villosa*, *Hemarthria altissima*, *Setaria nigrirostris*, *Trachypogon spicatus*, *Urochloa panicoides*. Herbs: *Acanthospermum australe*, *Centella asiatica*, *Conyza podocephala*, *Haplocarpha scaposa*, *Helichrysum herbaceum*, *H. nudifolium* var. *pilosellum*, *Hermannia depressa*, *Hibiscus aethiopicus* var. *ovatus*, *Ipomoea crassipes*, *Kohautia amatymbica*, *Lessertia harveyana*, *Pentanisia prunelloides* subsp. *latifolia*, *Rhynchosia effusa*, *Senecio retrorsus*, *Stachys aethiopica*, *Tolpis capensis*, *Vernonia natalensis*. Herbaceous Climber: *Rhynchosia totta*. Geophytic Herbs: *Cheilanthes deltoidea*, *C. hirta*, *Haemanthus humilis* subsp. *hirsutus*, *Ledebouria sandersonii*, *Rhodohypoxis baurii* var. *baurii*, *Watsonia pillansii*, *Zantedeschia albomaculata* subsp. *albomaculata*. Low Shrubs: *Anthospermum rigidum* subsp. *pumilum* (d), *Chaetacanthus setiger*, *Erica caffrorum* var. *caffrorum*, *Felicia filifolia* subsp. *filifolia*, *F. muricata*, *Helichrysum dregeanum*, *Rubus rigidus*. Succulent Shrub: *Euphorbia clavarioides* var. *clavarioides*.

Biogeographically Important Taxon (Sub-Escarpment Grassland endemic) Small Tree: *Encephalartos friderici-guilielmi*.

Endemic Taxa Herbs: *Alepidea duplidens*, *Berkheya griquana*, *Wahlenbergia dentata*, *W. ingrata*.

Conservation Vulnerable. Target 23%. Only 0.2% is statutorily conserved in the Malekgonyane (Ongeluksnek) Wildlife Reserve and Mount Currie Nature Reserve. Over one quarter of the area has already been transformed for cultivation (maize), plantations and by urban sprawl. *Acacia dealbata* and *A. mearnsii* are invading these grasslands in some places. Erosion is low (31%), very low (30%) and moderate (30%).

References Acocks (1953, 1988), Hurt et al. (1993), Camp (1999b).

Gs 13 Mabela Sandy Grassland

VT 56 Highland Sourveld to *Cymbopogon-Themeda* Veld Transition (Eastern Free State Highveld) (95%) (Acocks 1953). LR 42 Moist Upland Grassland (100%) (Low & Rebelo 1996). BRG 14 Sour Sandveld (65%) (Camp 1999c).

Distribution KwaZulu-Natal and Eastern Cape Provinces: Cedarville Flats (basin draining into Umzimvubu River) in the region of Cedarville-Matatiele (southwestern KwaZulu-Natal) as well as a small area in a basin of Simi and Ramohlakoana in the Kinira River Valley in Transkei (west of Matatiele). Altitude 1 440–1 500 m, but up to 1 550 m in a few places.

Vegetation & Landscape Features Flat valley basins with a relatively high proportion of poorly drained soils with a generally low nutrient status. Dominated by species-poor, low tussock-dominated, sour grasslands without indigenous trees, with *Sporobolus pyramidalis* and *Aristida junciformis* as indicator species.

Geology & Soils Tarkastad Subgroup mudstones and sandstones underlie this area to the east as do the Molteno and Elliot Formation sandstones and minor mudstones in the west (all of the Karoo Supergroup). The dominant soils are poorly drained, with a depth of 200–300 mm and a clay content of less than 15%. They are classified into soil forms of Katspruit and Longlands and Oatsdale, Vimy and Clovelly (in well-drained habitats). Most common land types Ia and Ca.

Climate Summer rainfall, with MAP of around 710 mm and mean evaporation up to 1 700 mm. MAT 14.4°C. Frost very frequent (40 days per year). See also the climate diagram Gs 13 Mabela Sandy Grassland (Figure 8.61).

Important Taxa Graminoids: *Abildgaardia ovata* (d), *Andropogon eucomus* (d), *Cynodon dactylon* (d), *C. incompletus* (d), *Elionurus muticus* (d), *Eragrostis patentissima* (d), *Heteropogon contortus* (d), *Paspalum distichum* (d), *Pennisetum clandestinum* (d), *Setaria sphacelata* (d), *Sporobolus pyramidalis* (d), *Themeda triandra* (d), *Tristachya leucothrix* (d), *Aristida bipartita*, *A. congesta*, *A. junciformis* subsp. *galpinii*, *Brachiaria eruciformis*, *B. serrata*, *Cymbopogon pospischilii*, *Digitaria argyrograpta*, *D. monodactyla*, *D. ternata*, *D. tricholaenoides*, *Ehrharta calycina*, *Eragrostis capensis*, *E. chloromelas*, *E. gummiflua*, *E. plana*, *E. racemosa*, *Harpochloa falx*, *Hyparrhenia hirta*, *Imperata cylindrica*, *Microchloa caffra*, *Pennisetum thunbergii*, *Setaria nigrirostris*, *Sporobolus discosporus*, *Stipagrostis zeyheri* subsp. *sericans*, *Tragus racemosus*, *Trichoneura grandiglumis*. Herbs: *Acanthospermum australe*, *Monopsis decipiens*, *Psammotropha mucronata* var. *foliosa*. Geophytic Herbs: *Bulbine narcissifolia*, *Zantedeschia albomaculata* subsp. *albomaculata*. Geoxylic Suffrutex: *Elephantorrhiza elephantina*.

Conservation Vulnerable. Target 23%. Only a very small part statutorily conserved in the Malekgonyane (Ongeluksnek) Wildlife Reserve. More than 20% already transformed for cultivation (maize) and by urban sprawl. Threats to the remaining grasslands are heavy selective grazing by livestock, particularly in communal areas. Overgrazing increases the risk of local erosion.

Remark Much of the bottomland area is subject to floods and therefore extensive sites of AZf 3 Eastern Temperate Freshwater Wetlands are found embedded within this vegetation unit.

References Acocks (1953, 1988), Camp (1999c), KZN DAEA (2003).

Gs 14 Mthatha Moist Grassland

VT 44 Highland Sourveld and Dohne Sourveld (81%) (Acocks 1953). LR 42 Moist Upland Grassland (90%) (Low & Rebelo 1996).

Distribution Eastern Cape Province: Plains between Mthatha and Butterworth parallel to the coastline and excluding the river valleys that intrude landwards into this unit. Altitude 600–1 080 m.

Vegetation & Landscape Features Undulating plains and hills supporting species-poor, sour, wiry grassland with *Eragrostis plana* and *Sporobolus africanus*; although in good condition, it is more likely to be dominated by *Themeda triandra*.

Geology & Soils Mudstones of the Tarkastad and Adelaide Subgroups (Beaufort Group, Karoo Supergroup) underlie this area, with highly leached soils typical of the Fa land type.

Climate Summer rainfall, with MAP 600–970 mm. The coefficient of variation of MAP 25–30% across the unit, but drops to approximately 15% on the southeast-facing inland mountain slopes. Incidence of frost 2–14 days, but is higher further from the coast. See also climate diagram for Gs 14 Mthatha Moist Grassland (Figure 8.61).

Important Taxa Graminoids: *Cyperus obtusiflorus* var. *obtusiflorus* (d), *Elionurus muticus* (d), *Eragrostis curvula* (d), *Heteropogon contortus* (d), *Microchloa caffra* (d), *Paspalum dilatatum* (d), *Sporobolus africanus* (d), *Themeda triandra* (d), *Abildgaardia ovata*, *Alloteropsis semialata* subsp. *eckloniana*, *Aristida congesta*, *Brachiaria serrata*, *Chloris virgata*, *Cymbopogon marginatus*, *Cynodon dactylon*, *Cyperus haematocephalus*, *C. obtusiflorus* var. *flavissimus*, *Digitaria eriantha*, *D. ternata*, *Eragrostis capensis*, *E. plana*, *Eustachys paspaloides*, *Harpochloa falx*, *Hemarthria altissima*, *Hyparrhenia hirta*, *Panicum ecklonii*, *Paspalum scrobiculatum*, *Setaria nigrirostris*, *Tristachya leucothrix*. Herbs: *Senecio coronatus* (d), *Centella asiatica*, *Chamaecrista mimosoides*, *Cyanotis speciosa*, *Eriosema salignum*, *Falkia repens*, *Helichrysum rugulosum*, *Indigofera*

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Figure 8.68 Gs 14 Mthatha Moist Grassland: Over-grazed grassland on a stony slope near Tsolo (Eastern Cape). The yellow-flowered daisy is the unpalatable *Senecio coronatus* (Asteraceae).

hedyantha, *I. hilaris* var. *hilaris*, *Ipomoea crassipes*, *Lobelia flaccida*, *Pentanisia prunelloides* subsp. *latifolia*, *Senecio retrorsus*, *Sonchus dregeanus*, *Vernonia capensis*, *V. natalensis*, *Wahlenbergia stellarioides*. Herbaceous Climber: *Rhynchosia totta*. Geophytic Herbs: *Boophone disticha*, *Habenaria dives*. Small Tree: *Acacia natalitia*. Low Shrubs: *Senecio pterophorus* (d), *Coddia rudis*, *Erica caffrorum* var. *caffrorum*, *Felicia filifolia* subsp. *filifolia*, *Hermannia parviflora*.

Biogeographically Important Taxon (Sub-Escarpment Grassland endemic) Small Tree: *Encephalartos friderici-guilielmi*.

Conservation Endangered. Target 23%. Only a small fraction is statutorily conserved in the Luchaba and Nduli Wildlife Reserves. More than 40% transformed for cultivation and plantations or by dense rural human settlements. Previously cultivated or fallow lands possibly constitute an estimated additional 25% (Steenkamp et al. 2005). *Acacia mearnsii*, *Solanum mauritianum* and *Richardia humistrata* are the most important aliens. Erosion a serious problem, with high to very high erosion levels in 34% of the unit, moderate erosion in 35%, and the remainder having low and very low erosion.

Remarks There is a high level of utilisation of this unit leading to degradation and transformation and the vegetation shows various stages of overutilisation (Steenkamp et al. 2005). Shifting cultivation and the effects of development have caused continuous disturbance of the soil surface, which has led to secondary succession changes in the grassland (documented in Smits et al. 1999). Poor grazing management has led to the dominance of unpalatable grasses and invasion by weedy, mostly alien, forb species (Hoare 2002).

References Acocks (1953, 1988), Smits et al. (1999), Hoare (2002), Steenkamp et al. (2005).

Gs 15 Tsomo Grassland

VT 44 Highland Sourveld and Dohne Sourveld (49%), VT 22 Invasion of Grassveld by *Acacia karroo* (36%) (Acocks 1953). LR 42 Moist Upland Grassland (51%) (Low & Rebelo 1996).

Distribution Eastern Cape Province: In the region to the east of the Queenstown Basin. The villages of Tsomo, Cala and Engcobo define the eastern extent of this unit and Cathcart, Queenstown and Sterkstroom the western extent. This vegetation unit occupies the plains in between the mountain peaks and ridges in this region. Altitude 760–1 580 m.

Vegetation & Landscape Features Flat or gently undulating lowland plains intersected by mountains. The vegetation is a grassland or open thornveld, often grazed short or replaced by dwarf shrubland dominated by species of *Euryops*. Dominant and common species include omnipresent representatives of the genera *Cymbopogon*, *Elionurus*, *Eragrostis*, *Aristida* and *Themeda*. Asteraceae and Fabaceae are prominent among the forbs.

Geology & Soils Mudstones of the Tarkastad Subgroup (Karoo Supergroup) overlain mostly by soils of moderate depth typical of Fb and Db land types.

Climate Late summer rainfall, although some rain may fall at other times of the year. MAP 430–790 mm, increasing from west to east. The coefficient of variation in MAP 25–31% across the unit. Incidence of frost is variable (7–65 days), but is higher in the northwest. See also climate diagram for Gs 15 Tsomo Grassland (Figure 8.61).

Important Taxa Graminoids: *Aristida congesta* (d), *Cynodon dactylon* (d), *Digitaria argyrograpta* (d), *Elionurus muticus* (d), *Eragrostis chloromelas* (d), *E. curvula* (d), *E. plana* (d), *Eustachys paspaloides* (d), *Heteropogon contortus* (d), *Hyparrhenia hirta* (d), *Microchloa caffra* (d), *Themeda triandra* (d), *Tragus berteronianus* (d), *Abildgaardia ovata*, *Andropogon appendiculatus*, *Aristida diffusa*, *Brachiaria serrata*, *Cymbopogon pospischilii*, *Eragrostis capensis*, *E. lehmanniana*, *E. racemosa*, *Harpochloa falx*, *Microchloa kunthii*, *Schoenoxiphium sparteum*, *Sporobolus africanus*, *Tristachya leucothrix*, *Urochloa panicoides*. Herbs: *Argyrolobium pauciflorum*, *Aster bakerianus*, *Berkheya onopordifolia* var. *onopordifolia*, *Commelina africana*, *Cyanotis speciosa*, *Gazania linearis* var. *linearis*, *Haplocarpha scaposa*, *Helichrysum rugulosum*, *Ipomoea crassipes*, *Pollichia campestris*, *Senecio retrorsus*, *Vernonia capensis*. Herbaceous Climber: *Rhynchosia totta*. Geophytic Herbs: *Oxalis depressa* (d), *Pelargonium sidoides*. Small Tree: *Acacia natalitia*. Low Shrubs: *Chaetacanthus setiger*, *Felicia muricata*, *Helichrysum odoratissimum*, *Senecio burchellii*, *Sutera pinnatifida*, *Tephrosia capensis* var. *acutifolia*. Tall Shrub: *Euryops floribundus* (d).

Conservation Vulnerable. Target 23%. None conserved in statutory conservation areas. Only 1% conserved in private reserves. Some 27% transformed mainly for cultivation and by dense concentrations of rural settlements. Increased occurrence of alien *Schkuhria pinnata* and *Tagetes minuta* indicates heavy disturbance. Erosion is a serious problem and it is high in 33% of this unit, moderate in 32%, and low and very low in 34% of the area.

Remarks The name is derived from the village of Tsomo, which falls entirely within this plains type vegetation, the others tending to occupy positions on adjacent slopes. There is high rural occupancy and utilisation of this unit, leading to degradation and transformation. A number of dams of medium size have also been built within this unit. The vegetation shows various stages of overutilisation and also a gradient from grassland to thornveld. Mountain ridges within this unit are often wooded

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Figure 8.69 Gs 15 Tsomo Grassland: Over-grazed grassland with abundant species of *Aristida* and *Elionurus muticus* and the invading unpalatable shrub *Euryops floribundus* (Asteraceae) near Tsomo (former Transkei, Eastern Cape).

and this woody component easily spreads into the surrounding vegetation where ecological conditions permit. Many of the other vegetation units in the region, both grassland and woody vegetation, grade into this one, so that there is a naturally high rate of species turnover.

References Acocks (1953, 1988), Hoare & Bredenkamp (2001).

Gs 16 Queenstown Thornveld

VT 22 Invasion of Grassveld by *Acacia karroo* (77%) (Acocks 1953). LR 44 South-eastern Mountain Grassland (52%) (Low & Rebelo 1996).

Distribution Eastern Cape Province: From the vicinity of Queenstown in the east to the vicinity of Tarkastad in the west, and Sterkstroom in the north. Altitude 980–1 500 m.

Vegetation & Landscape Features Flat bottomlands of intramountain basins with adjacent slopes supporting a complex of *Acacia natalitia* thornveld and grassland dominated by *Aristida congesta*, *Cymbopogon pospischilii*, *Eragrostis curvula* and *Tragus koelerioides*, with scattered shrubs and low *Acacia* in places (Hoare 1997, Hoare & Bredenkamp 1999).

Geology & Soil Sedimentary rocks of the Tarkastad Subgroup (Beaufort Group, Karoo Supergroup) overlain with clay-loam soils typical of Da and Fc land types.

Climate Rainfall peaks in late summer. MAP mainly 380 mm in the west, increasing to 640 mm in the east. The coefficient of variation in MAP from 28–34% across the unit. Incidence of frost is 22–58 days, higher in the northwest than the southeast. See also climate diagram for Gs 16 Queenstown Thornveld (Figure 8.61).

Important Taxa Small Tree: *Acacia natalitia* (d). Tall Shrub: *Euryops floribundus* (d). Low Shrubs: *Asparagus laricinus*, *Atriplex semibaccata* var. *appendiculata*, *Felicia filifolia* subsp. *filifolia*, *F. muricata*, *Helichrysum asperum* var. *albidulum*, *H. dregeanum*, *Melolobium microphyllum*, *Pentzia globosa*, *Sutera pinnatifida*, *Tephrosia capensis* var. *acutifolia*. Succulent Shrub: *Hertia pallens*. Graminoids: *Aristida canescens* (d), *A. congesta* (d), *A. diffusa* (d), *Cymbopogon pospischilii* (d), *Cynodon incompletus* (d), *Digitaria argyrograpta* (d), *D. eriantha* (d), *Eragrostis chloromelas* (d), *E. curvula* (d), *E. lehmanniana* (d), *E. obtusa* (d), *E. trichophora* (d), *Heteropogon contortus* (d), *Microchloa caffra* (d), *Panicum stapfianum* (d), *Themeda triandra* (d), *Tragus koelerioides* (d), *Brachiaria serrata*, *Cynodon dactylon*, *Cyperus usitatus*, *Elionurus muticus*, *Eustachys paspaloides*, *Microchloa kunthii*, *Sporobolus fimbriatus*, *Tragus racemosus*. Herbs: *Arctotis microcephala*, *Blepharis integrifolia* var. *clarkei*, *Commelina africana*, *Cyanotis speciosa*, *Gazania krebsiana* subsp. *krebsiana*, *Helichrysum pedunculatum*, *H. rugulosum*, *Hermannia depressa*, *Indigofera alternans*, *Salvia stenophylla*, *Senecio asperulus*, *Tribulus terrestris*. Herbaceous Climber: *Rhynchosia totta*. Geophytic Herbs: *Oxalis corniculata*, *O. depressa*.

Conservation Least threatened. Target 23%. Nearly 1% statutorily conserved in the Tsolwana Nature Reserve. Some 10% transformed primarily by cultivation and urbanisation. Urbanisation of this unit is expanding at a rapid rate and the amount of transformation due to this factor may be higher. Overgrazing in this vegetation unit is serious, especially by goats close to urban areas. Erosion is high (24%), moderate (54%), low and very low (22%).

Remark A core community of this vegetation landscape was described as the *Trago koelerioidis–Acacietum karroo* by Hoare (1997).

References Acocks (1953, 1988), Low & Rebelo (1996), Hoare (1997), Hoare & Bredenkamp (1999).

Gs 17 Tarkastad Montane Shrubland

VT 60 Karroid *Danthonia* Mountain Veld (25%), VT 22 Invasion of Grassveld by *Acacia karroo* (23%), VT 37 False Karroid Broken Veld (20%) (Acocks 1953). LR 52 Eastern Mixed Nama Karoo (37%), LR 44 South-eastern Mountain Grassland (33%) (Low & Rebelo 1996).

Distribution Eastern Cape and marginally into Northern Cape Province: Noupoort, Middelburg and a point west of Cradock define the western extent of this unit and Cathcart, Queenstown and Sterkstroom the eastern extent. The unit falls within the area between the Great Escarpment in the north, marked by the Bamboesberg and Stormberg Mountains, and the minor escarpment, marked by the Winterberg and Amathole Mountains in the south. Altitude 1 020–1 780 m.

Vegetation & Landscape Features Ridges, hills and isolated mountain slopes, characterised by high surface rock cover, this often consisting of large, round boulders. The vegetation is low, semi-open, mixed shrubland with 'white' grasses and dwarf shrubs forming a prominent component of the vegetation.

Geology & Soils Sedimentary rocks of the Tarkastad Subgroup (Beaufort Group, Karoo Supergroup), widely affected by intrusions of Jurassic dolerites forming numerous dykes and sills. Soils typical of land types Ib, Fb and Fc.

Climate Rainfall in late summer to autumn (peak in February–March). MAP 280–720 mm (overall MAP 470 mm),

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Figure 8.70 Gs 16 Queenstown Thornveld: *Acacia natalitia* thornveld near Sada and the Waterdown Dam south of Queenstown (Eastern Cape) with the undergrowth containing grasses such as *Cymbopogon pospischilii*, *Aristida congesta*, *Tragus koelerioides* and *Heteropogon contortus*.

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Figure 8.71 Gs 17 Tarkastad Montane Shrubland: The rare cycad *Encephalartos friderici-guilielmi* in the shade of *Cussonia paniculata* in montane shrubland close to the Waterdown Dam south of Sada (Eastern Cape).

increasing from west to east. Coefficient of variation of MAP from 22–35% across the unit (31% overall APCV), decreasing with distance eastwards. Incidence of frost 7–68 days (average: 39 days), increasing with proximity to the Escarpment. See also climate diagram for Gs 17 Tarkastad Montane Shrubland (Figure 8.61).

Important Taxa Succulent Tree: *Aloe ferox* (d). Small Tree: *Acacia karroo* complex. Tall Shrubs: *Diospyros austro-africana* (d), *Cadaba aphylla*, *Ehretia rigida*, *Rhus burchellii*, *Tarchonanthus minor*. Woody Climbers: *Asparagus racemosus*, *A. retrofractus*. Low Shrubs: *Euryops annae* (d), *Aptosimum elongatum*, *Asparagus striatus*, *Blepharis mitrata*, *B. villosa*, *Chrysocoma ciliata*, *Diospyros pallens*, *Eriocephalus ericoides*, *Felicia filifolia* subsp. *filifolia*, *F. muricata*, *Gymnosporia heterophylla*, *Helichrysum dregeanum*, *H. zeyheri*, *Hermannia filifolia*, *Indigofera sessilifolia*, *Lantana rugosa*, *Limeum aethiopicum*, *Melolobium microphyllum*, *Nenax microphylla*, *Pegolettia retrofracta*, *Pentzia globosa*, *Phymaspermum parvifolium*, *Rosenia humilis*, *Sutera pinnatifida*, *Wahlenbergia albens*. Succulent Shrubs: *Lycium schizocalyx*, *Pachypodium succulentum*, *Sarcocaulon camdeboense*. Semiparasitic Shrub: *Thesium hystrix*. Graminoids: *Aristida adscensionis* (d), *A. congesta* (d), *A. diffusa* (d), *Cynodon incompletus* (d), *Enneapogon scoparius* (d), *Eragrostis chloromelas* (d), *E. lehmanniana* (d), *E. obtusa* (d), *Heteropogon contortus* (d), *Tragus berteronianus* (d), *T. koelerioides* (d), *Chloris virgata*, *Cymbopogon pospischilii*, *Digitaria eriantha*, *Eragrostis curvula*, *Eustachys paspaloides*, *Fingerhuthia africana*, *Sporobolus fimbriatus*, *Themeda triandra*, *Tragus racemosus*. Herbs: *Commelina africana*, *Gazania krebsiana* subsp. *krebsiana*, *Hibiscus pusillus*, *Indigofera alternans*, *Lepidium africanum* subsp. *africanum*, *Tribulus terrestris*. Geophytic Herbs: *Asplenium cordatum*, *Boophone disticha*, *Cheilanthes deltoidea*, *C. hirta*, *Oxalis depressa*. Succulent Herb: *Crassula muscosa*.

Biogeographically Important Taxa ([SE]Sub-Escarpment Grassland endemic, [E]Eastern distribution limit) Small Tree: *Encephalartos friderici-guilielmi*[SE]. Low Shrubs: *Eriocephalus africanus*[E], *Senecio acutifolius*[E].

Conservation Least threatened. Target 28%. Around 1–2% conserved in statutory conservation areas (Commando Drift, Tsolwana Nature Reserves, Mountain Zebra National Park). About 2% transformed for cultivation or by building of dams (Kommandodrif and Waterdown). Erosion is moderate (51%), high (28%) and low (18%).

Remarks Physiographically similar landscapes to the north support Gh 4 Besemkaree Koppies Shrubland and to the west (along the Great Escarpment) NKu 2 Upper Karoo Hardeveld. These two units and the current unit are all shrublands primarily associated with dolerite intrusions. The Upper Karoo Hardeveld has lower rainfall, but the Besemkaree Koppies Shrubland is distinguishable climatically (on the basis of slightly lower minimum temperatures and higher summer rainfall) and floristically.

References Acocks (1953, 1988), Palmer (1988, 1989, 1991a, b), Rubin & Palmer (1996), Brown & Bezuidenhout (2000), De Klerk et al. (2003), Brown & Bezuidenhout (2005).

Gs 18 Bedford Dry Grassland

VT 21 False Thornveld of Eastern Province (40%), VT 68 Eastern Province Grassveld (25%) (Acocks 1953). Dry Bedford Grassland (Martens & Morris 1994, Martens et al. 1996). Moist Bedford Grassland (Martens et al. 1996). LR 15 Subarid Thorn Bushveld (71%) (Low & Rebelo 1996).

Distribution Eastern Cape Province: South of the Winterberg Mountains from Bruintjieshoogte and Somerset East in the west to Bedford and Adelaide, and to Fort Beaufort in the east. The eastern section lies north of the Great Fish River Valley. Altitude 480–990 m.

Vegetation & Landscape Features Gently undulating plains supporting open, dry grassland interspersed with *Acacia karroo* woodland vegetation (especially along the drainage lines). The grassland is relatively short (10–100 cm) and is dominated by *Digitaria argyrograpta*, *Tragus koelerioides*, *Eragrostis curvula* and *Cymbopogon caesius*. It contains a dwarf shrubby component of karroid origin in the southern and southwestern parts of its range.

Geology & Soils Loam or clay-loam soils typical of Fc (most of the region) as well as Db and Fb land types on the mudstones and sandstones of the Adelaide Subgroup (Beaufort Group, Karoo Supergroup).

Climate Bimodal rainfall occurring in spring and late summer. MAP 310–550 mm. MAP is relatively uniform across this unit, but increases closer to the mountains and slightly from west to east. The coefficient of variation in MAP varies from 28–35% across the unit. Incidence of frost 3–31 days, higher towards the west than the east. See also climate diagram for Gs 18 Bedford Dry Grassland (Figure 8.61).

Important Taxa Graminoids: *Cynodon dactylon* (d), *C. incompletus* (d), *Cyperus usitatus* (d), *Digitaria argyrograpta* (d), *D. eriantha* (d), *Eragrostis capensis* (d), *E. chloromelas* (d), *E. curvula* (d), *E. obtusa* (d), *Heteropogon contortus* (d), *Microchloa caffra*

(d), *Panicum maximum* (d), *P. stapfianum* (d), *Sporobolus fimbriatus* (d), *Themeda triandra* (d), *Tragus koelerioides* (d), *Aristida congesta*, *A. diffusa*, *Cymbopogon caesius*, *C. pospischilii*, *Eragrostis plana*, *Eustachys paspaloides*, *Melica decumbens*, *Setaria sphacelata*, *Sporobolus nitens*. Herbs: *Cyanotis speciosa* (d), *Blepharis integrifolia* var. *clarkei*, *Chamaesyce inaequilatera*, *Commelina africana*, *Emex australis*, *Gazania krebsiana* subsp. *krebsiana*, *Helichrysum rugulosum*, *Hermannia althaeifolia*, *H. coccocarpa*, *Lepidium africanum* subsp. *africanum*. Geophytic Herbs: *Oxalis depressa*, *Pelargonium sidoides*. Succulent Herb: *Crassula expansa*. Small Tree: *Acacia karroo*. Low Shrubs: *Atriplex semibaccata* var. *appendiculata* (d), *Helichrysum dregeanum* (d), *Nenax microphylla* (d), *Asparagus striatus*, *Chrysocoma ciliata*, *Euryops anthemoides* subsp. *anthemoides, Felicia muricata*, *Garuleum latifolium*, *Hermannia althaeoides*, *Indigofera sessilifolia*, *Jamesbrittenia microphylla*, *Limeum aethiopicum*, *Lycium cinereum*, *Melolobium burchelli*, *Pelargonium aridum*, *Pentzia globosa*, *Selago fruticosa*, *S. saxatilis*, *Talinum arnotii*, *Tephrosia capensis* var. *acutifolia*. Succulent Shrubs: *Cotyledon orbiculata* var. *oblonga*, *Mestoklema tuberosum*.

Conservation Least threatened. Target 23%. None conserved in statutory conservation areas and only 1% conserved in private reserves (Kingsdale Game Farm, Woodlands Game Reserve, Glen Avon Falls Kloof and Kruizemuntfontein Natural Heritage Sites). Some 3% transformed for cultivation. Erosion high in 25% of this unit, moderate in 31% and low to very low in 44%.

Remarks Drainage lines within this unit contain *Acacia karroo*-dominated woodland and the incised river valleys intruding from the south of this unit contain AT 8 Kowie Thicket and NKl 4 Albany Broken Veld. The grasslands of this unit furthest from the mountain range have a strong karroid element which enters from the dry Great Fish River Valley. This grassland unit falls within the Albany CE, which contains an extensive endemic flora, especially of succulents. The Smaldeel area is considered to be an important goat production area (Martens & Morris 1994, Martens et al. 1996).

References Acocks (1953, 1988), Martens & Morris (1994), Martens et al. (1996), Hoare (1997), Hoare & Bredenkamp (1999).

9. Credits

The introductory text is a team effort by D.B. Hoare and L. Mucina, assisted by R.A. Ward (geology: Section 3.2) and L. Scott (palaeoecological patterns: Section 2.1). M.C. Rutherford extensively edited the introductory text and contributed especially to Sections 2.2 and 3.1.

The original subdivision of the Grassland Biome into bioregions was coined by L. Mucina and modified by M.C. Rutherford. The conceptual delimitation of the Drakensberg Grassland units as currently accepted in our chapter is the result of co-operation between D.B. Hoare (Southern Berg units), M.C. Rutherford (Lesotho units) and L. Mucina (other, especially Free State and KwaZulu-Natal Gd units). The units occurring (if only in part) in KwaZulu-Natal were delimited on the basis of K.G.T. Camp's map of resource units and their boundaries further modified by L. Mucina and C.R. Scott-Shaw. D.B. Hoare and L. Mucina co-authored the units Gd 2–4. The unit Gd 1 was coined and described by D.B. Hoare as sole author. The units Gd 6 and 7 were co-authored by C.R. Scott-Shaw, K.G.T. Camp and L. Mucina, while the units Gd 8–10 were co-authored by M.C. Rutherford and L. Mucina. P.J. du Preez and L. Mucina were instrumental in the circumscription of the units Gh 1–9. They were assisted by D.B. Hoare in units Gh 1 and 2 and by G.J. Bredenkamp in Gh 3, 5, 6 and 9. The units Gh 10–15 were described through a team effort by H. Bezuidenhout, L. Mucina, G.J. Bredenkamp and S.S. Cilliers. L.W. Powrie helped to delimit the unit Gh 4. The major effort in mapping delimitation and description of the Gm units was contributed by M.C. Lötter (units Gm 6, 8, 11–18 and 21–27, 29), L. Mucina (Gm 1–12, 15, 22–24, 26, 28 and 29), M.C. Rutherford (Gm 2, 4, 5, 8, 9, 11, 13–15, 18–21, 28 and 29) and G.J. Bredenkamp (Gm 4, 6, 8, 10–13, 16, 18–20, 22 and 23). D.B. Hoare contributed to units Gm 8–12, P.J. du Preez to units Gm 1, 3–7 and J.E. Burrows to Mpumalanga units Gm 14, 16–18, 21, 22 and 24. P.J.D. Winter defined Gm 25 and contributed map boundaries for Limpopo sections of units Gm 11, 23 and 25–27. M. Stalmans participated in four Mpumalanga (Gm 22 and 23) and Limpopo (26 and 27) units. S.J. Siebert and F. Siebert contributed substantially to the Sekhukhune Grassland units (Gm 19 and 20). The following colleagues each contributed to one Montane Grassland unit: K. Kobisi and L. Kose (Gm 2), L.W. Powrie (Gm 5), C.R. Scott-Shaw (Gm 15), L. Dobson (Gm 16), E. Schmidt (Gm 17), P.J.D. Winter (Gm 25) and T.H. Mostert (Gm 28). The major contributors to Gs units were K.G.T. Camp (whose boundaries were followed in many cases; co-author of Gs 1, 6–13), C.R. Scott-Shaw (co-author of Gs 1, 3, 4 and 6–13), M.C. Lötter (co-author of Gs 1, 3 and 7) and D.B. Hoare (author of mapping concepts and descriptions of the Eastern Cape units Gs 14–18). L. Mucina co-authored almost all Gs units (except Gs 2, 14 and 15), M.C. Rutherford contributed to Gs 4, 6, 12 and 16 and G.J. Bredenkamp to unit Gs 3. The Ithala Quartzite Sourveld unit (Gs 2) was coined by M.C. Lötter and J.E. Burrows. The species lists were compiled by L. Mucina on the basis of source data provided by particular authors of the descriptions of vegetation units. L.W. Powrie assisted with extraction of species lists from the SANBI databases (PRECIS, ACKDAT). M.C. Lötter and M. Stalmans assisted in checking the endemic status of species in Mpumalanga vegetation units, while C.R. Scott-Shaw helped with a similar check for KwaZulu-Natal units. E.G.H. Oliver kindly checked the *Erica* species in each vegetation unit. R.A. Ward kindly checked and corrected the sections on geology in all descriptions of the vegetation units. L.W. Powrie was instrumental in the preparation of working versions of mapping material for the contributors at various stages of the Project. G.J. Bredenkamp was technically assisted with GIS expertise by W.H. de Frey and R.A.J. Robesson during the initial mapping of the northern provinces. We also acknowledge the help of R.G. Bennett and C. Oellerman.

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Plants

Plants, we adore you, the ones who cover the world!
Your species are distributed all around the world,
In rocky areas and in flood plains, you grow,
In wet soils and sandy soils, you grow,
Your seeds grow well,
In favourable conditions, your seeds grow,
In unfavourable conditions, your seeds persist.

So abundant, where do you get the feet to stretch?
So abundant, where do you get the tricks to grow?
The blanket that covers the whole world,
The beauty of the world,
You are not only beautiful, but also the king,
Human race and animals equally adore you.

Grow in abundance,
Like an orphan, be persistent, be strong, and carry on,
Grow in abundance, cover the world and bring resolutions,
Resolutions bringing end to poverty and diseases,
Emerging diseases of this world,
Such are the epidemics of HIV and AIDS.

by M.A. Dladla (English translation by E.M. Daemane)

Savanna Biome

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1. Introduction: Delimitation and Global Perspective

The savanna vegetation of South Africa and Swaziland constitutes the southernmost extension of the most widespread biome in Africa. It represents 32.8% of South Africa (399 600 km^2) and 74.2% of Swaziland (12 900 km^2). It extends beyond the tropics to meet the Nama-Karoo Biome on the central plateau, the Grassland Biome at higher altitudes towards the east and extends down the eastern seaboard interior and valleys where it grades into Albany Thicket in the Eastern Cape.

More specifically, savanna occupies most of the far-northern part of the Northern Cape, the western and northeastern parts of North-West Province, extreme western parts of the Free State Province, northern Gauteng with more isolated occurrences in the south of this province, almost the entire Limpopo Province, northwestern and northeastern Mpumalanga, most of central and eastern Swaziland, low-altitude parts of the eastern seaboard, inland of the Indian Ocean Coastal Belt in KwaZulu-Natal and the Eastern Cape Provinces, and with the southernmost extension abutting Albany Thicket of the Komga to Albany Districts.

Savannas are largely tropical and occupy the greater area of the southern continents (Huntley & Walker 1982) and also some parts of the northern continents. Most of the savannas are associated with old planation surfaces and are believed to represent a legacy of the vegetation which flourished during the Tertiary and even earlier geological periods when under hot, wet climatic conditions laterisation processes were active (Cole 1982, 1986). Savanna types north of South Africa and Swaziland extend from southern Mozambique in the east and

from the central interior of Namibia in the west through to the coast of central Angola and to the margins of evergreen tropical forest of the Congo Basin and extend further north into eastern Africa. Most of this area of savanna in south-central Africa south of Kenya (and excluding Botswana, Namibia, South Africa and Swaziland) is the miombo woodland or savanna. From Kenya, savanna extends into southernmost Somalia and to the southern and western flanks of the Ethiopian highlands. From here it extends east-west as a great belt between the Sahel to the north and the humid semideciduous forests to the south in West Africa to reach the coast of Senegal (Okigbo 1985, Scholes & Walker 1993). In South America, main savanna forms are the moist cerrado positioned between the Amazon forest and the Atlantic forest in Brazil and the arid caatinga east of the cerrado in northeast Brazil (Eiten 1982, Cochrane et al. 1985) and at least parts of arid chaco mainly in Paraguay and Argentina with parts in Bolivia and Brazil (Bucher 1982). The Orinoco savannas (llanos) occur from the Guaviare River in Colombia to the east coast of Venezuela (Sarmiento 1983, Medina & Silva 1990). Areas of savanna are also found in the Guayana region of Venezuela. Savanna woodlands in Australia are widespread north of the Tropic of Capricorn (Gillison 1983) but also extend southwards in eastern Australia (Lacey et al. 1982, Mott et al. 1985). Savannas on northern continents are limited, and occur mainly in India as well as in various other parts of southeast Asia (Blasco 1983, Pemadasa 1990, Yadava 1990). Savanna is also found in southwest Texas and into northern Mexico (Archer 1990). Savanna can also occur as small isolated areas, e.g. on the Nicoya Peninsula in the extreme west of Costa Rica (Sarmiento 1983). Many dominant grass genera of southern African savanna are shared with savannas of other continents. These include, for example, *Heteropogon* (Africa, India, Australia and America), *Andropogon* (Africa, India and America) and *Themeda* (Africa, India and Australia) (Johnson & Tothill 1985).

More recent major reviews that include southern African savanna are those of Huntley & Walker (1982), Bourlière (1983), Tothill & Mott (1985) and Cole (1986), with other reviews including Furley (2004). For definitions of savanna and considerations for its delimitation in southern Africa see the chapter on Biomes and Bioregions.

2. Climate, Geology and Soils

2.1 Climate

The macroclimatic patterns of the Savanna Biome region are tightly linked to climatic differences between the Atlantic and Indian Ocean coasts of the southern African subcontinent. Among the major macroclimatic traits characterising the Savanna Biome are: (1) seasonality of precipitation (alternation of wet summer and dry winter periods), and (2) (sub)tropical thermal regime with no or usually low incidence of frost. Brief inspection of maps of southern Africa featuring average temperature regime and temperature differences reveal several major trends (see Schulze & McGee 1978), such as (a) an expected overall temperature increase towards the equator (hence the regions of Mopane Savanna bioregion showing the highest yearly temperatures), (b) isotherms being parallel along long stretches of the coast indicating the ameliorating thermal influence of the sea, and along the Indian Ocean coast of the warm Agulhas Current, and (c) the high summer maxima in the Kalahari region as well as increasing differences between minimum and maximum temperatures towards the interior, reflecting the thermal continentality effect.

The steep precipitation gradient spanning the west and east coasts is ascribed to various factors, among which the earth's largest cross-continental zonal asymmetry of tropical convection is supposed to play a major role (Stokes et al. 1997). In the southwestern Indian Ocean, the Inter-Tropical Convergence Zone (ITCZ) reaches its southernmost position at 23° S in the austral summer (Schneider 1996), causing the Indian Ocean to reach temperatures as high as 27.5°C at these latitudes (mid-value for January). In the eastern Atlantic, on the other hand, the ITCZ is seldom found south of 5° S (Stokes et al. 1997). On the other side of the subcontinent, in the southern Atlantic Ocean, the sea surface temperature is almost 6°C lower than at the same latitude in the Indian Ocean—possibly a combined effect of low convection and the cold Benguela Current. The relative position and latitudinal and longitudinal movements of South Atlantic and South Indian Ocean Anticyclones (or cells of high pressure) as well as more to the south, Ferrar lows have been invoked as another, very important source of the precipitation patterns in southern Africa (for detailed discussion of these climatic systems see Tyson 1986). As also noted by the latter author, Streten (1980) and later also Harrison (1986) argued that the anticyclone affecting (eastern) southern Africa in winter is not the South Indian Ocean Anticyclone, but a separate one which owes its origin to anticyclongenesis in a poleward stream of subsiding air originating in the Indian monsoon system of Asia. The regions occupied by the Savanna Biome clearly have a summer-rainfall regime. Stokes et al. (1997) argued that the elevated southern African land mass cools through long-wave emission, thereby providing an interhemispheric sink for Asian monsoon outflow. In summer, the Mascarene Anticyclone propels tropical easterlies—waves of moisture-laden tropical air over the eastern regions of the southern African continent, bringing abundant rain to the Savanna Biome. These waves get blocked in their westward movement by the relatively stable high-pressure system with its core located offshore of the West Coast over the Benguela Current, causing the summer aridity of the western regions of the subcontinent.

Savanna in South Africa and Swaziland does not occur at high altitudes and is found mostly below 1 500 m and extending to 1 800 m on parts of the highveld mainly along the southernmost edges of the Central Bushveld. Temperatures are therefore higher than those of the adjacent Grassland at higher altitudes. The mean daily maximum temperature for February rarely drops below 26°C and exceeds 32°C in the Kalahari region and some low-altitude parts of savanna in the east (Schulze 1997a). In July this temperature remains above 20°C for most of the area, with some temperatures at the highest altitudes dropping to 18°C. The mean daily minimum temperature in February rarely drops below 16°C, with the temperature of substantial parts of lower lowveld remaining above 20°C. The very low occurrence of positive chill units in savanna outside the highveld and Ghaap Plateau area, suggests the irrelevance of a chilling period for breaking dormancy in most savanna plants. Minimum temperatures in winter are much more variable across savanna. In limited areas in the extreme east, the mean daily minimum temperature for July remains above 10°C but drops to below 0°C on the highveld (southern edge of the Central Bushveld) and high-altitude parts of the Eastern Kalahari Bushveld such as the Ghaap Plateau. The average dates of heavy frost are also the earliest (May) and latest (September) in the two last-named areas. In savanna, the Ghaap Plateau shows the longest period in the year when frosts can occur (>120 days). Only lower-lying parts of the Mopane, Lowveld and Sub-Escarpment Savanna Bioregions can be regarded as frost-free. Diurnal temperature ranges (T_{max} minus T_{min}) also differ considerably across savanna from a range of <9°C in Eastern Valley Bushveld to >15°C in

SVkd 1 Gordonia Duneveld in February. Corresponding values for winter (July) are about 12°C and >18°C, respectively. Mean annual temperature varies from about 16°C on parts of the highveld to >22°C in some lower parts of the Lowveld. Summer heat units correlate especially well with savanna, with most of the area with heat units above 2 200 degree days (October–March, base 10°C) falling within savanna. Summer (January) solar radiation is the lowest (< 28 $MJm^{-2}d^{-1}$) in the eastern parts of savanna (Lowveld and Sub-Escarpment Savanna) and highest (>34 $MJm^{-2}d^{-1}$) in the southern parts of Kalahari Duneveld (Schulze 1997b). In July this drops to a low (<13 $MJm^{-2}d^{-1}$) in the southern parts of Sub-Escarpment Savanna (Schulze 1997a).

MAP varies from less than 200 mm in the west in southern Gordonia Duneveld to about 1 350 mm at the highest altitude parts of Swaziland Sour Bushveld in the east. Outside the Kalahari areas, most of the savanna experiences a MAP of between 500 mm and 750 mm. Coefficients of variation in annual precipitation vary from over 35% in the dry west to less than 25% in the more mesic parts of the east (Schulze 1997a). Concentrations of rainfall are generally high in savanna, peaking at a concentration index of more than 65% in the Kalahari Duneveld and northern parts of the Central Bushveld and Mopane regions (Schulze 1997a). A concentration index of 100% implies that the rainfall of a location is very concentrated in a single month, while 0% means that the rain in all months of the year is the same. Most of the savanna has rainfall concentrated in midsummer (January) but in late summer (February) in the Kalahari areas. There are some areas of savanna in the east, especially at higher altitudes, that have rainfall concentration in early summer (December).

Worldwide, savanna has a strongly seasonal rainfall with wet summers and dry winters (Nix 1983). Savanna has a distinct dry season, with most of the area in South Africa receiving less than 5 mm of rain in each of the months of June, July and August. Only in parts of the Sub-Escarpment Savanna is this slightly exceeded (especially in August). Most savanna areas in southern Africa have what is classified as strong summer rainfall or summer rainfall (Bailey 1979, Rutherford & Westfall 1994).

Although savannas have a distinct dry season and, in southern Africa, with a wet season that is essentially unimodal, there are areas of savanna, such as those of northern Tanzania, Kenya and southern Ethiopia, that have very distinctive bimodal rains usually with the 'short rains' peaking around November and the 'long rains' peaking around April, with the dry season centred in July. The summer-rainfall depression (lowest in February) in some of these savanna areas can be considerable, dropping to less than 10% of that of the peak rainfall month of the short rains, effectively creating a second, but shorter dry season (especially in southern Ethiopia and more arid parts of Kenya; Müller 1982). The magnitude of the rainfall in the 'long' and 'short' rainy seasons can be very similar in some areas in the north of the region. There are many species of southern African savanna that also thrive in these strongly bimodal rainfall systems.

The pattern of relative humidity in summer generally approximates the MAP pattern but in winter the relative humidity in the western part of savanna forms a belt of lowest values from around Lephalale (Limpopo Province) to Van Zylsrus (Northern Cape Province) and shows higher humidity into the lower-rainfall area of southwestern Gordonia, possibly due to the influence of cyclonic systems from the west during winter. Nowhere in South African savanna do winter daily minimum relative humidities (i.e. those that typically occur at the hottest period of the day) reach the extremely low levels experienced in savanna some hundreds of kilometres to the north of the country in the central parts of southern Africa where values of close to 0% have been recorded. Potential evaporation in summer (January) is low in parts of the Sub-Escarpment Savanna (<180 mm A-pan equivalent), but increases northwards in the Central Bushveld (200–300 mm) and westwards to high values in Gordonia Duneveld (>360 mm). The extreme variation in potential evaporation in savanna is reflected in the mean annual amounts which vary from less than 1 600 mm in parts of Eastern Valley Bushveld of the eastern seaboard area to more than 3 000 mm in Nossob Bushveld of the Kalahari.

Hail and flash density of lightning on the ground are relatively low compared to that in the surrounding Grassland Biome. Surface winds are generally light in the region of South African savanna, although on the Polokwane Plateau strong winds from the east are sometimes experienced in summer (Schulze 1965). Savanna includes some areas of relatively windless conditions with, for example, Pretoria experiencing a frequency of 41% calms in January and 57% in July.

There has been a long local history of relating the climate of a region to its vegetation, especially in KwaZulu-Natal (Phillips 1983). Climate regions as relating to zones of vegetation have also been proposed at the national level in South Africa (Kruger 2004). Climatic relationships with a number of different savanna species in southern Africa have been established (e.g. Rutherford et al. 1999a, b). By way of but one example, areas where mean annual rainfall of less than 400 or 450 mm intersect with the highest number of heat units (in South Africa) correspond closely to that area of the Limpopo River Basin (and that of some of its tributaries) in which *Adansonia digitata* (Figure 9.2) occurs in South Africa.

2.2 Geology

In South Africa, the Savanna Biome is located mostly in the northeastern part of the country. The geology of this area is dominated by a very stable block of ancient continental crust, known as the Kaapvaal Craton. The Kaapvaal Craton began to form by a process of accretion over 3.5 billion years ago (gya) and has been largely unaffected by crustal processes, except on its fringes, for the last 2 ga. The craton also hosts a number of significant sedimentary basins and igneous intrusions, thus preserving a geological record spanning most of geological time.

The Barberton mountain lands consist of some of the oldest rocks on earth and preserve the first evidence of the assembly of the Kaapvaal Craton (Poujol et al. 2003). This area includes the Barberton Greenstone Belt, a volcano-sedimentary sequence, as well as granitoid and gneissose rocks to the north and south. To the south of the greenstone belt is the Ancient Gneiss Complex in Swaziland which hosts the oldest rocks on the craton, some of which formed over 3.6 gya. Similar, but slightly younger greenstone belts are found elsewhere in the craton such as the Giyani, Murchison, Pietersburg and Kraaipan Greenstone Belts. These belts preserve clastic and chemical sediments as well as volcanic rocks that characteristically include ultramafic extrusives.

The assembled crustal blocks and associated greenstone belts were thickened and stabilised by the intrusion of many large bodies of potassic granitoid rocks that started around 3.1 gya. Such batholiths include the Nelspruit, Mpuluzi and Heerenveen bodies.

This stabilised crust became the basement on which large deposits of sediments could form and be preserved to the present day. The rich gold fields of South Africa formed among the sedimentary rocks of the Witwatersrand Supergroup that were deposited between 3 and 2.7 gya. This thick succession

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Figure 9.2 *Adansonia digitata* (baobab) with shrubs of *Grewia flava* on the edge of a sandstone ridge at an altitude of 555 m in the Mapungubwe National Park in early April. The baobab is one of the earliest savanna tree species to drop its leaves after summer in South Africa.

of quartzite, conglomerate and shale formed the world's greatest gold resource due to a unique set of circumstances on the stable crustal block during the Late Archaean. It was at a similar time that the Pongola Supergroup sediments were deposited to the east.

It is believed that these basins formed during the approach and eventual collision of the Kaapvaal Craton and a similarly stable block, the Zimbabwe Craton. Shortly after the deposition of the Witwatersrand sediments ceased, a phase of rift-related volcanism and associated sedimentation formed the thick Ventersdorp Supergroup. Rocks of this succession cover large areas of the North-West Province. This marked the end of significant tectonic activity on the craton.

During the early Proterozoic, subsidences lead to the development of stable continental platforms on parts of the craton that formed large sedimentary basins. The two large basins were the Transvaal basin, near the centre of the craton, and the Griqualand West basin on the western edge. Hence, the Griqualand West Supergroup correlates both chronologically and genetically to the Transvaal Supergroup. These two successions host similar deposits, most noticeably thick packages of chemical sediments (of the Ghaap and Chuniespoort Groups, respectively), including dolomites and Banded Iron Formations (BIF). The BIFs host important iron and manganese deposits for the country and, interestingly, formed as a result of (cyclically) elevated oxygen levels in the atmosphere and oceans due to the sudden increase of photosynthetic organisms (blue-green algae).

Deposition of the Transvaal Sequence continued for several hundred million years, amounting to a total thickness of accumulated sediment of over 20 km.

At ca. 2 060 mya the intrusion of the Bushveld Igneous Complex (BIC) formed one of the most recognisable features on the Kaapvaal Craton. This enormous structure forms the largest layered mafic intrusion on earth and is also host to the greater part of the world's platinum group metal, vanadium and chromium resources. It is intrusive into the upper part of the Transvaal Supergroup, namely between the Pretoria Group below, and the Rooiberg Group above. The intrusion consists of a mafic part that formed its characteristic compositional layering by means of a settling out of minerals from the melt as they crystallised and is known as the Rustenburg Layered Suite. The other part of the intrusion consists of a voluminous amount of granitic material that lies above the mafic part, in the centre of the structure. This is the Lebowa Granite Suite and it contains some large fragments of older Transvaal Supergroup rocks.

Shortly after the intrusion of the BIC, another event around 2 gya generated the interesting Vredefort Dome. This structure has at its core Swazian Erathem basement gneiss and surrounding this, sediments of the Witwatersrand and Transvaal Supergroups which become younger away from the core. Until recently the reason for this doming and extreme up-warping of the basement and overlying sediments remained enigmatic. The interpretation of shock-metamorphism of the gneiss associated with the doming event is that a meteorite strike was the cause. This catastrophic event resulted in the rebounding of the crust to form what is now called the Vredefort impact structure.

Between ca. 1.9 and 1.6 gya the clastic sediments of the Soutpansberg and Waterberg Groups were deposited in the northern part of the craton. At a similar time the sediments and volcanics of the Olifantshoek Supergroup were laid down on the western edge of the craton. These are all of the Mokolian Erathem.

The next significant sedimentary basin to form on the Kaapvaal Craton was the Karoo Basin, during more recent times. The Karoo was one of several basins on the Gondwana Supercontinent, of which the Kaapvaal Craton formed a part, covering a total area of some 4.5 million km^2 during early Permian times (Smith et al. 1993). Sediments and volcanics of the Karoo cover large parts of the craton and its boundaries with adjacent crustal material.

The boundaries of the craton are in fact the zones of pervasively deformed rocks that represent old orogenic (mountain-building) events that occurred after 2.7 gya. The Limpopo Belt to the north of the craton represents the collision between the Kaapvaal and Zimbabwe cratons beginning at around 2.7 gya. Remobilisation of this orogenic belt occurred at around 2 gya, hence it forms the northern boundary of the craton. To the south and west of the craton, the mesoproterozoic (ca. 1 gya) Namaqua-Natal Metamorphic Belt forms the craton boundary. This belt extends from KwaZulu-Natal, beneath the younger Karoo rocks that cover it in the interior to the Namaqualand region and into Namibia. The Namaqua-Natal Metamorphic Belt is one of several belts of similar age throughout the world.

Although kimberlite pipes occur across large parts of southern Africa, it is only those that intruded into a craton that bear diamonds. Those that intruded into the Namaqua-Natal Metamorphic Belt or further west, are barren. This is consistent with the fact that the conditions for diamond growth are only found beneath old, rigid cratonic crust.

For more detailed accounts of the geology that include savanna areas, see Smith et al. (1993), Thomas et al. (1994), Eriksson et al. (1995), Robb & Meyer (1995), Brandl & De Wit (1996) and Poujol et al. (2003).

2.3 Soils

Since the early 1970s, our knowledge on the distribution and properties of soils has increased significantly, especially in the traditionally uncultivated parts of the country. Careful field observations of soil-plant relationships in the savanna regions by MacVicar (1962), Van Rooyen (1971), Verster (1974), Eloff (1984), Venter (1990) and others, including land type surveys (Land Type Survey Staff 1984a, b, c, 1985, 1986a, b, 1987, 1988, 1989a, b) have made it possible to understand the ecological significance of the soils better. The land type survey programme was initiated by the Department of Agriculture (later the ARC Institute of Soil, Climate and Water) in 1972.

With our improved knowledge of the occurrence and main properties of different soils, we can determine how they are likely to behave under a certain set of given environmental factors. For example, it is now known that there exists a much closer relationship between soils and vegetation in dry regions, such as much of the savanna areas, than in higher-rainfall regions (e.g. the surrounding mesic parts of the Grassland Biome). In low-rainfall areas, where water is the main limiting growth factor, it is mainly those physical factors that determine the rainfall efficiency, that have the greatest influence on the vegetation composition.

Local influences of soil properties (e.g. variation on a scale of as small as 0.25 ha) may have a pronounced influence on the pattern and type of tree-grass coexistence in an area. Such properties may be soil crust formation (Mills 2003) on certain soils (enhancing water runoff and therefore less available soil water in the profile, but possibly raising available nutrient levels; Dougill & Thomas 2004), swelling (cracking) clay soils that formed on basic parent materials (high storing capacity for soil water but with seasonal root pruning taking place), duplex soils with a root-impenetrable clay pan below or skeletal soils (shallow, usually also stony soils, but with fissures and cracks in the saprolite where some water may be stored and roots may penetrate).

Under extreme conditions of a high evapotranspiration and low annual rainfall (e.g. Kalahari), deep soils are needed for the trees and shrubs to survive. As the rainfall increases and the evapotranspiration decreases, shallower soils can also support the growth of trees and shrubs. Where duplex soils with a prismacutanic B-horizon (e.g. Estcourt soil form) dominate within a region, grass will dominate over trees and shrubs. Similarly, where high clay content swelling soils occur, despite favourable climate-soil water conditions, grasses will dominate because they can adapt to seasonal root pruning better than the perennial trees and shrubs. Grass quality, i.e. foliar nutrients, can also be closely related to soil texture (Mutanga et al. 2004).

The contributions of the different soil groups per broad savanna region are given in Box A. In the broad Kalahari area, Van Rooyen (1971) reported that the strongest relation between soil and vegetation was found on the deep red sandy soils (Hutton soil form (Orthic A—Red apedal B); Soil Classification Working Group 1991). The soils are base-saturated and have a considerable water storage capacity. *Acacia erioloba* and *A. haematoxylon* plants serve as distinctive indicators of these soils when they are generally deeper than 1 m. On the same soils but on slightly higher elevations than the former and on northern slopes, dense communities of *A. mellifera* and *A. tortilis* dominate. In contrast to vegetation on the deep red soils, on yellow-coloured, sandy but calcareous soils [Augrabies (Orthic A—Neocarbonate B—Unspecified) and Addo soil form (Orthic A—Neocarbonate B—Soft carbonate B)], treeless grass vegetation dominates. Very little soil covers the dolomite formation of the Ghaap Plateau. The soils are usually calcareous [Coega soil form (Orthic A—Hardpan Carbonate)], with *Tarchonanthus camphoratus*, *Olea europaea* subsp. *africana* and some *Rhus* species. Red, yellow and greyish, excessively drained sandy soils (arenosols according to WRB terminology, where WRB is the World Reference Base for Soil Resources of the International Society for Soil Science (ISSS), the International Soil Reference and Information Centre (ISRIC) and the Food and Agriculture Organization (FAO) of the United Nations) dominate the dune areas (Box A). While these soils are still dominant in the areas where savanna vegetation occurs, deep red weakly structured soils (some of which might be calcareous below) with a slightly higher clay content than the dune sands occupy about one third of the area. It is on these soils (mostly luvisols and some calcisols) where most of the trees and shrubs occur. Shallow soils on rock (mostly leptosols) dominate on the ridges.

In Central Bushveld and including Mopane Savanna the soil variation is quite large (Box A). Although deep red weakly structured soils with a loamy to clay texture dominate on the more level land, soils with a high clay content and swelling properties (mostly vertisols and phaoezems) occupy almost 10% of the area. Where the region borders with the Grassland Biome to the south, the soils are mostly red and yellow, weakly structured with a low to medium base status, reflecting a higher effective rainfall than in the rest of the region. Shallow soils on rock (mostly leptosols) also dominate on the ridges and low mountains, while many rock outcrops occur on some of the mountains. On the shallow gravelly coarse sand of the Wasbank [Orthic A–E—Hardpan ferricrete (broken type)] and Glenrosa (Orthic A—Lithocutanic B—Saprolite) soil forms carry various woody plants including *Combretum zeyheri*, *C. apiculatum* and *Acacia caffra* (Verster 1974). These plants seem to be adapted to soils with a relatively dry soil climate, strong to medium acid conditions and a low inherent soil fertility. On the other hand, no trees (with the exception of a few) have been reported on

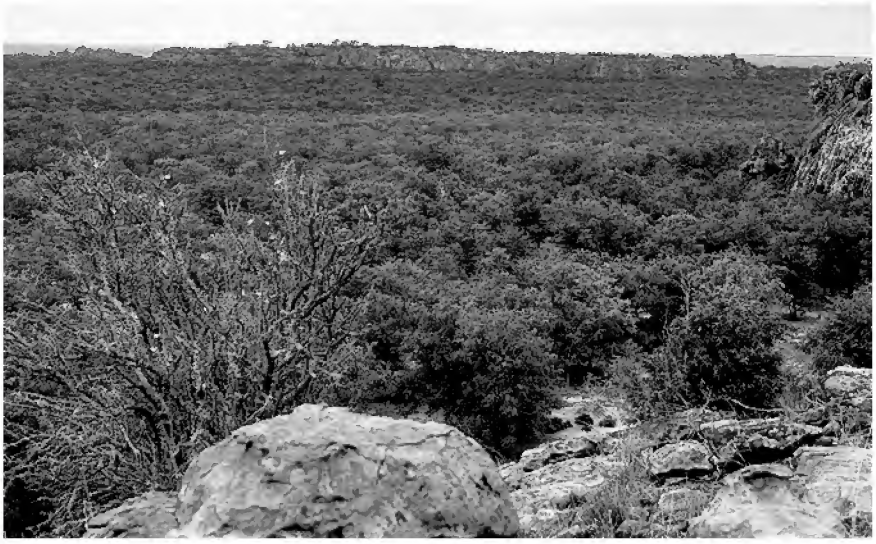

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Figure 9.3 *Colophospermum mopane* overwhelmingly dominant on the heavier soils on the plains of Musina Mopane Bushveld with *Sesamothamnus lugardii* in the foreground, uncharacteristically on rock, in the Mapungubwe National Park (Limpopo Province).

the shallow coarse sand of the Wasbank and Dresden (Orthic A—Hardpan ferricrete) soil forms where the ferricrete is hard and solid below. Here grasses (e.g. *Trachypogon spicatus*) dominate. On many imperfectly drained floodplains (e.g. the Nyl River east of Mookgophong) with calcareous moderately structured clay soils [Sepane soil form (Orthic A—Pedocutanic B—Unconsolidated material with signs of wetness)], *Spirostachys africana*, *Acacia mellifera* and *A. tortilis* dominate. These plants therefore can tolerate the seasonally wet conditions, the stronger soil structure and prefer the high base status. In the mopane veld north of the Soutpansberg Mountains, *Colophospermum mopane* seems to be the best adapted to the unfavourable environmental conditions where it occurs on red and dark-coloured loamy and clay soils (Figure 9.3). In contrast, the perennial grasses such as species of *Digitaria*, *Schmidtia* and *Eragrostis* prefer the more sandy soils in this region. Only certain tree and shrub species are present on the black swelling clay ('turf') soils [mainly Arcadia soil form (Vertic A—Saprolite)]. It seems that *Acacia tortilis*, *A. robusta*, *A. nilotica*, *A. tenuispina* and *A. karroo* can tolerate the swelling properties of these soils.

In Lowveld bushveld, Venter (1990) has used the land type concept as basis for his ecological studies and management planning of the Kruger National Park (KNP). He found that a significant correlation existed between geology, landform and soils. Differences in these parameters were well reflected in both species composition and structural features of the vegetation that form the basis for habitat differentiation within the KNP.

The soil variation in this region is also quite large with soils of almost all soil groups present (Box A). However, it is the soils with limited pedological development (mostly leptosols) that dominate the area, with soils with high clay content and swelling properties (mostly vertisols and phaeozems that are associated with the base-rich parent materials, e.g. basalt) that have the highest percentage coverage of all the Savanna Biome groups. Here again, as with the Central Bushveld region, where the region borders on the Grassland Biome to the west, the soils are mostly red and yellow, weakly structured and with a low to medium base status, reflecting a higher effective rainfall than the rest of the region.

Box A. Relative contribution of soil groups within each savanna bioregion.

Bioregion	Soil group (%)											
	A2	A3	A4	A5	AR	B1	B2	C1	D1	E1	G1	H1
Central Bushveld	6	2	38	2	6	3	0	1	9	19	12	2
Mopane	0	0	32	0	16	0	0	4	1	45	0	1
Lowveld	8	1	7	1	5	1	1	2	15	53	3	0
Sub-Escarpment Savanna	6	2	1	0	0	0	1	5	1	83	0	0
Eastern Kalahari Bushveld	0	0	27	1	49	0	0	2	0	17	5	0
Kalahari Duneveld	0	0	1	0	99	0	0	0	0	0	0	0

Soil groups are as follows (classification according to World Reference Base (WRB) soil groups given in brackets):

Red-yellow well-drained soils lacking a strong texture contrast:

A2—Red and yellow, massive or weakly structured soils with low to medium base status (association of well-drained Ferralsols, Acrisols and Lixisols). Land type: Ab.

A3—Red and yellow, massive or weakly structured soils with medium to high base status (association of well-drained Ferralsols, Acrisols and Lixisols and one or more of Regosols, Leptosols, Calcisols and Durisols). Land types: Ac & Ad.

A4—Red, massive or weakly structured soils with high base status (association of well-drained Lixisols, Cambisols, Luvisols). Land type: Ae.

A5—Red, massive or weakly structured soils with high base status (association of well-drained Lixisols, Cambisols, Luvisols and one or more of Regosols, Leptosols, Calcisols and Durisols). Land types: Ag & Ah.

Soils within a plinthic catena:

B1—Red, yellow and greyish soils with low to medium base status (association of Ferralsols, Acrisols, Lixisols and Plinthosols. In addition, other soils with plinthic and gleyic properties may also be present). Land types: Ba & Bb.

B2—Red, yellow and greyish soils with high base status (association of Lixisols, Cambisols, Luvisols and Plinthosols. In addition, other soils with plinthic and gleyic properties may also be present). Land types: Bc & Bd.

Soils with a strong texture contrast:

C1—Soils with a marked clay accumulation (association of Luvisols, Planosols and Solonetz. In addition, one or more of Plinthosols, Vertisols and Cambisols may be present). Land types: Da, Db & Dc.

Soils with a high clay content and swelling properties:

D1—Black and red, strongly structured clayey soils with high base status (association of Vertisols, Phaeozems, Kastanozems and Nitisols. In addition, one or more Leptosols, Calcisols and Cambisols may be present). Land type: Ca.

Soils with limited pedological development:

E1—Soils with minimal development, usually shallow on hard or weathering rock, with or without intermittent diverse soils (association of Leptosols, Regosols, Calcisols and Durisols. In addition, one or more of Cambisols, Luvisols and Phaeozems may be present). Land types: Fa, Fb & Fc.

AR—Red, yellow and greyish excessively drained sandy soils (Arenosols). Land types: Af & Ha.

H1—Soils with negligible to weak profile development usually occurring on recent flood plains (association of Fluvisols, Cambisols, Luvisols and Gleysols). Land type: Ia.

Rocky areas:

G1—Rock with limited soils (association of Leptosols, Regosols, Durisols, Calcisols and Plinthosols). Land types: Ib & Ic.

Within the Sub-Escarpment Savanna, MacVicar (1962) has done some pioneering work on correlating soil with vegetation types in the Tugela Basin. The soil variation in the region is similar to what has been described for the Lowveld, also quite large, with soils of almost all soil groups present (Box A). There is, however, an absence of rocky areas and very sandy (red and greyish coloured, weakly structured) soils and deep soils that occur on large floodplains. Large areas of soils with high clay content that have swelling properties are also very limited. Although the soil group that represents soils with limited pedological development covers about 80% of the whole region, it actually indicates a great variation in the occurrence of soil types (without any of the other soil groups that dominate). One can therefore expect that, besides leptosols, soils such as regosols, cambisols, luvisols, planosols and phaeozems will occur. Again, where the region borders on the Grassland or Afrotemperate Forest Biomes to the west and north, the soils are mostly red and yellow, weakly structured and with a low to medium base status, reflecting a higher effective rainfall than the rest of the region.

3. Biogeography: Origins, Diversity Patterns and Classifications

3.1 Origins of the Savanna Flora and Vegetation

Judging from the wide extent of the Zambezian or Sudano-Zambezian Floristic Region and similarities of broad-leaved woodland and thorn bushland on both sides of the equator (White 1983, O'Brein & Peters 1999), evolution of the southern African savanna must have occurred in a wide African context. Middle and Upper Cretaceous floras are remote in terms of age and therefore have little significance in our assessment of the modern southern African savanna woodland. For instance, late Cretaceous wood from Mahura Muthla, North-West Province (Bamford 2000), and fossil leaves and pollen from Orapa, Botswana (Scholtz in Rayner et al. 1991, Bamford 2000), may have Gondwana features, but the numerous dicotyledonous leaves and other plant remains from Orapa are not identifiable to modern family level (Bamford 2000). We therefore look for clues of the southern African savanna woodland in the Tertiary period rather than the Cretaceous. There is little direct fossil evidence for the origin of savanna vegetation from the Tertiary period in southern Africa, but clues exist of how the vegetation in the current savanna region of southern Africa could have developed during this time.

Pollen of families that are typical in African savanna woodland seems to be present since the early Tertiary (Muller 1981) although they did not at that stage, represent vegetation similar to the current types in Africa. Eocene fossil leaves from Tanzania of *Acacia* and Caesalpiniaceae suggest that woodland elements related to current savanna species were already present in Africa by this time (Herendeen & Jacobs 2000, Jacobs & Herendeen 2004). Fossil Eocene wood in southern Africa at Bogenfels in Namibia indicates the presence of families like Balanitaceae, Burseraceae, and Euphorbiaceae that have members in modern savanna woodland (Bamford 2000). Eocene wood from Mozambique (Bamford 2000) could give similar indications. More tropical conditions in the current savanna region, than at present, are likely to have prevailed for long periods in southern Africa during the Tertiary. We infer this from the observation that subtropical vegetation occurred in the southern and southwestern Cape and Namaqualand regions during the Palaeogene and Early Neogene (Coetzee & Rogers 1982, Scholtz 1985, Scott 1995, Bamford 2000). For example, Bamford (2000) reported on Lower and Middle Miocene wood of Combretaceae from the Namaqualand region indicating wetter and forested conditions. The observation that warmer ocean waters surrounded the subcontinent (Shackleton & Kennet 1975) supports this scenario.

For the Neogene (the Late Miocene and Early Pliocene), Axelrod & Raven (1978) and O'Brein & Peters (1999) envisage scenarios suitable for large expanses of broad-leaved and seasonal and semi-arid woodland in Africa. The development of modern savanna is closely linked with the evolution of C_4 photosynthesis in grasses that took place after 8.5 mya, possibly together with declining atmospheric pressures of CO_2 (Cerling et al. 1997, Ehleringer et al. 1997, Jacobs 2004, Sage 2004). Jacobs (2004) reviewed plant and vertebrate fossil evidence relating to savanna woodland development and suggests that forest changed to open woodland between 12.6 and 6.8 mya in the Tugen Hills, Kenya. The oldest finds of typical savanna components in the southern hemisphere of Africa (*Acacia*, Combretaceae, *Commiphora* and *Dichrostachys* pollen types) are recorded in marine sediment cores along Namibia from the Atlantic Ocean from Deep See Drilling Project cores off Angola and northern Namibia of Late Miocene (Partridge 1978) and Early Pliocene age (Van Zinderen Bakker 1980). Bonnefille (1995) reports the presence of fossil pollen typical of Sudano-Zambezian flora in 4 mya (Pliocene) sediments from East Africa. Several fossil wood fragments from Member 4 in the Sterkfontein Cave include a liana typical of riverine and gallery forest, suggesting that trees were present at the time between 2.8–2.6 mya (Bamford 2000, Partridge 2000). Pliocene uplift in southern Africa and cooling (Partridge et al. 1995) seem to correspond with a transition from closed to more open woodland as inferred from fossil antelope faunas from sediments in South African hominid sites representing the period between 2.6 and 2 mya (Vrba 1985, 1995). Open grassy *Protea* savanna occurred by then on the boundary between the current Savanna and Grassland Biomes as indicated by pollen in deposits from Kromdraai and Sterkfontein (Scott & Bonnefille 1986, Scott 1995). The situation was different from but resembled the contemporary one.

Long-term boundary shifts and changes in floral composition in the Neogene were a characteristic feature of the vegetation history following regular transitions from glacial, stadial and interglacial conditions. These regular cyclic changes are visible in a stalagmite isotope record from Lobatse Cave (Holmgren et al. 1995), and in pollen records over the last 200 000 years from the Tswaing Crater (Pretoria Saltpan) and Wonderkrater (near Mookgophong), suggesting transitions from broad-leaved savanna to other types like montane forests, upland fynbos, thornveld or even karoo-like vegetation (Scott 1982, 1999a, b). During moist phases, for instance ca. 50 000 yr BP montane forests with *Podocarpus/Afrocarpus* and *Olea* must have occupied parts of the interior plateau that is currently under savanna woodland. During coldest Last Glacial Maximum (LGM) times between ca. 30 000 to 16 000 years ago, grassland with fynbos replaced this vegetation, which found refugia at lower elevations. Pollen spectra covering the last 20 000 years at Wonderkrater were presented in a calibrated time scale of radiocarbon dates and reflect the history since the decline of upland fynbos during the LGM. Thornveld developed ca. 10 000 years ago, broad-leaved woodland ca. 7 000 years ago, and more open woodland, associated with Late Holocene cooling, ca. 5 000 years ago (Scott et al. 2003). A nearby stalagmite record (stable isotopes) in the Makapansgat Valley provides a much higher resolution than the pollen record (Holmgren et al. 2003). Apart from the millennial-scale environmental changes

observed in both the pollen and stalagmite records, the stalagmite data show that the savanna vegetation was subject to short-term drought cycles on a decadal scale while the Little Ice Age represented a marked dry event ca. 1750 AD (Holmgren et al. 1999, 2003).

3.2 Diversity and Taxonomic Patterns

The number of species at broad geographical levels (gamma diversity) has been given as 5 788 (Gibbs Russell 1987) for the Savanna Biome in southern Africa, which in turn gives a relatively low species area ratio of 9.2 $10^3/10^6$ km^2 (Van Rooyen & Van Rooyen 1998). For the southern Kalahari part of this biome, the ratio drops even lower to 4.4 $10^3/10^6$ km^2 (Van Rooyen & Van Rooyen 1998). A broad-scale analysis indicates a gradient of sharply decreasing diversity of tree and larger shrub species from east to west within the Savanna Biome (O'Brien 1993, O'Brien et al. 2000). Cowling et al. (1997) found that heterogeneity (length of the temperature gradient) was the strongest predictor of regional species richness in South African savanna and grassland taken together. Savanna is well known for its diversity of mammals but many other animal groups are also well represented, for example dragonflies in the lowveld (Samways 1999).

An analysis of plant species diversity in the Sand River catchment in the lowveld revealed the following diversity patterns (Shackleton 2000b). The total number of species increased with increasing mean annual rainfall across the rainfall gradient, representing about 100 km from the border of the KNP to the eastern escarpment (Figure 9.4). Plant species numbers doubled over this gradient from around 50 to over 100 species per 0.1 ha. Plant species richness was substantially higher on eutrophic bottomlands than on dystrophic toplands. However, species turnover was greater along the rainfall gradient (about 85%) than along the catenal gradient between toplands and bottomlands (about 40%). There were significantly fewer species in protected areas than on the adjacent, highly utilised, communal lands. In the KNP, Whittaker et al. (1984) reported 78 plant species per 0.1 ha in habitat dominated by *Combretum zeyheri* and *Pterocarpus angolensis* and 93 species per 0.1 ha in habitat dominated by *C. zeyheri* and *C. apiculatum*.

In the Central Bushveld in the Nylsvley Nature Reserve, a similar range of plant species richness was found to that in the Lowveld (Whittaker et al. 1984: Table 4). The typical sandy savanna dominated by *Burkea africana* and *Terminalia sericea* had between 80 and 100 species per 0.1 ha, which is indicated to be high compared to diversity in various USA plant communities (Whittaker et al. 1984). The highest set of values were for an area unburned for more than four years. More moderate diversity levels of between 40 and 60 species per 0.1 ha were found on rocky hills dominated by *Diplorhynchus condylocarpon*, and areas with somewhat more clay (than the surrounding sands) dominated by *Acacia tortilis* and *A. nilotica*. This lower range is still ranked as 'moderately high' compared with plant communities in the USA (Whittaker et al. 1984). Cowling & Hilton-Taylor (1997) regard the southern African section of the (Sudano-) Zambesian (Floristic) Region as 'relatively depauperate'. Cowling et al. (1989, 1997) indicate an average of about 67 species per 0.1 ha for South African savanna from a variety of sources.

Van Rooyen & Van Rooyen (1998) extracted data at a slightly different scale (0.001 ha or 100 m^2) from Leistner & Werger (1973) to show various plant diversity patterns in the southwestern Kalahari. Species number per 0.001 ha was 32 on the red sand interdune valleys and dropped to 23 on the red sand dune tops in the north (with *Terminalia sericea* and *Albizia anthelmintica*), but only to 28 on the other dune tops (with *Stipagrostis amabilis*) common throughout the region. By contrast, the dune crests and slopes covered by red sand had the highest values according to the Shannon-Wiener index (which combines both richness and equitability) from 2.59 to 3.04. Beta diversity (turnover of species along a gradient) is extremely low for the communities of the large and homogeneous sandy areas (excluding riverbeds and pans) in the southwestern Kalahari.

At the point scale (1 m^2) in the Sand River catchment, means of 7.9 and 8.2 species were found for toplands and bottomlands, respectively (Shackleton 2000b). Cowling et al. (1989) indicated a point scale mean of 9 for the Savanna Biome. On a savanna site in Namibia (MAP approximately 520 mm), naturally protected from long-term herbivory or disturbance by larger ungulates and with many plant species in common with South African savanna, point diversity averaged only 5.1 species (Rutherford 1975). Out of 1 200 samples of 1 m^2, there were no empty points; 1.4% had only one species, whereas a similar low percentage of points had 10 or more species (maximum 13).

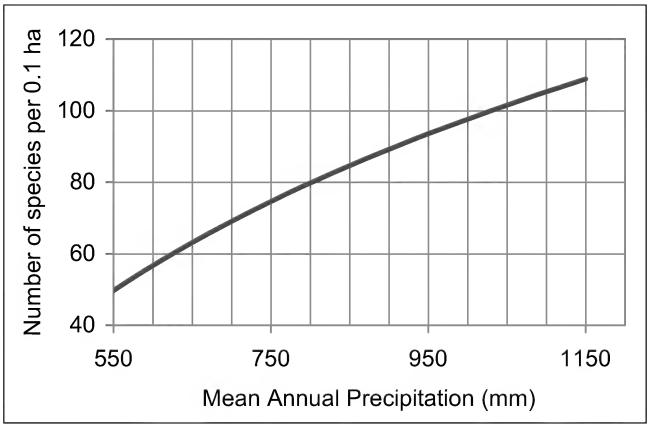

Figure 9.4 Relationship between mean annual rainfall and number of plant species in the Sand River catchment of the Lowveld (Mhala and Pilgrim's Rest Districts). Equation is: Number of species/ 0.1 ha = 80.09 ln(MAP) – 455.57 with $r^2 = 0.67$, $P < 0.00001$ and $n = 40$ (Shackleton 2000b).

3.3 Biogeographical and Vegetation Subdivisions

There is no widely accepted and overarching classification system for southern African savannas (Scholes 1997). At a very general phytochorial level, Werger (1978a) considers most of the savanna (and most grassland) in the present work to be part of the Zambezian Domain of the Sudano-Zambezian (Floristic) Region. However, he excluded the Kalahari area, which he placed within the Karoo-Namib Region, as the Southern Kalahari Subdomain. Kalahari has been delimited in many different, and often conflicting, ways (Thomas & Shaw 1991). White (1983) includes this area in the Sudano-Zambesian Phytogeographical Region. The area is, however, transitional between the tree and shrub flora of mainly Sudano-Zambesian affinity and the flora of the lower layers (at least in the Kalahari Duneveld Bioregion), with strong affinities with the Karoo-Namib Region (Werger 1973). The fact that the interdune valleys with mainly lower shrubs are wider than the parallel dunes that carry most of the larger shrubs and trees (Leistner & Werger 1973) was a deciding majority-area consideration in Rutherford & Westfall (1986) placing much of the Kalahari duneveld region in the structurally and climatically defined Nama-Karoo Biome and later extend-

ing it northwards (Rutherford & Westfall 1994: 74, Rutherford 1997) and including only the Nossob Bushveld in the far north in the Savanna Biome. This northern extension was also independently made through recent work on plant structure (Westfall & Van Staden 1996).

Werger & Coetzee (1978) recognised three broad vegetation units in the savanna of our region, namely 'Open *Acacia* savanna of the southern Kalahari' (corresponding to the Eastern Kalahari Bushveld and Kalahari Duneveld Bioregions), '*Colophospermum mopane* vegetation' (corresponding to the Mopane Bioregion) and 'Other woodland, savanna, thicket and bushveld vegetation' (corresponding to the Central Bushveld, Lowveld and Sub-Escarpment Bioregions). Their three units extend farther into Africa to limited degrees. Half of the 'Open *Acacia* savanna of the southern Kalahari' is in South Africa and extends towards Windhoek in Namibia, with a minor extension into southwestern Botswana. The 'Other woodland, savanna, thicket and bushveld vegetation' extends into large sections of central and northern Botswana and parts of central-north Namibia as well as into the far southern part of Mozambique. In this view, the savannas of South Africa and Swaziland are different to much of the rest of savanna (notably miombo) in Africa. The '*Colophospermum mopane* vegetation' does occur farther north, but then only as far as the southwestern corner of Angola and parts of the Zambezi River Valley with the most northerly extension up the Luangwa River Valley in Zambia (Henning & White 1974). Of the eight countries with this vegetation, South Africa is least represented (after Malawi) with only 4% of the total area of *Colophospermum mopane* vegetation (Mapaure 1994). There are, however, floristic elements in some South African savannas that re-occur in most African savannas. For example, the *Burkea africana* tree that occurs in several vegetation units of the Central Bushveld Bioregion is found to varying degrees in most of the African savanna to the north and through West Africa (Rutherford 1982a). The vegetation of the main study site of the South African Ecosystems Research Programme in the Nylsvley Nature Reserve is dominated by *Burkea africana*, and has also sometimes been regarded an impoverished form of miombo vegetation (Scholes & Walker 1993).

Huntley (1982) recognised two broad divisions of savanna (also applying to savannas northwards to the equator). These were moist/dystrophic savanna and arid/eutrophic savanna also called broad-leaved savanna and fine-leaved savanna, respectively (with mopane's broad-leaved being regarded as the exception; Scholes 1997). As mapping units, Huntley's (1982) moist/dystrophic savanna corresponds to the higher-lying areas of the Central Bushveld Bioregion (and to the eastern escarpment slopes west of the Lowveld; Huntley 1984). The arid/dystrophic savanna corresponds to the lower-lying parts of the Central Bushveld Bioregion and to the Lowveld, Sub-Escarpment Savanna, Mopane, Eastern Kalahari Bushveld and Kalahari Duneveld Bioregions. Scholes (1997) introduced a type intermediate between these two major units called 'mixed savanna', which corresponds to most of the Central Bushveld and Lowveld Bioregions (and also occurs in part of central Zimbabwe).

4. Vegetation Structure and Dynamics

4.1 Vegetation Structure and Patterns

Most savanna has a herbaceous layer usually dominated by grass species and a discontinuous to sometimes very open tree layer. 'Savanna grasslands' may grade into 'tree savanna', 'shrub savanna', 'savanna woodland' or 'savanna parkland' (Scholes & Archer 1997). In many savanna areas in southern Africa the term bushveld is appropriate since the woody component does often not form a distinct layer as in miombo vegetation to the north but presents an irregular series of interlocking, often low, canopies with openings and sometimes little distinction between tall shrubs and small trees. This continuum between shrub and tree has been reflected in a 'shrubbiness index' developed for a range of savanna species in the Central Bushveld (Rutherford 1982b). Scholes et al. (2004) referred to 'stemminess' of savanna woody plants and pointed out that the distinction between trees and shrubs along a broad-scale Kalahari transect is somewhat arbitrary with savanna trees being typically multistemmed, but with fewer stems than shrubs. Structure of the woody component of savanna is important to animals—for example tree height which determines the available browse, dense woody entanglements forming impenetrable barriers, availability of shade, and protection against predators or scavengers. In arid savanna, such as the southwestern Kalahari, the configuration of the sparse woody component can also become critical as cover for hunting leopards (Bothma et al. 1994).

Floristically similar vegetation can be structurally different. For example, on black vertic clays, *Acacia tortilis* may form a woodland or occur as low shrubs embedded within grassland and kept low possibly by fire and frost (Van der Meulen & Westfall 1980). Substrate appears to play an important role in differentiating between the tall dominant trees of *Colophospermum mopane* on shale in SVmp 3 Cathedral Mopane Bushveld and the dominant shrubs of the same species in an adjacent vegetation unit (SVmp 4 Mopane Basalt Shrubland) on basalt in the KNP. Substrate also plays a key role in determining structure in the western parts of the Central Bushveld, where on particularly heavy clays (>55% clay in all horizons) most other woody plants are excluded and the diminutive *Acacia tenuispina* dominates at a height of less than 1 m above ground (Figure 9.5). On the sandy clay loam soils (with not more than 35% clay in the upper horizon, but high in the lower horizons) *A. erubescens* at over 5 m tall is the most prominent tree (Pauw 1988) (Figure 9.6). Some other plant relationships with soils are discussed in the section on soils.

The moist and arid savanna types (see Section 3.3) do not only differ predictably with lower woody plant leaf area index (LAI) and canopy cover (Privette et al. 2004) as well as basal cover (Scholes et al. 2002) in the arid savanna type. Finer but distinct structural differences include tree leaves changing from a horizontal orientation to a more random orientation and a strong decline in specific leaf area in arid savanna (Scholes et al. 2004), which, together with decreased LAI, indicates thinner leaves in arid savanna (along a Kalahari transect). Even when rainfall is similar, soil fertility differences result in nutrient-poor savanna (with many properties of moist savanna) and nutrient-rich savanna (with many properties of arid savanna). The nutrient-poor savanna also differs from nutrient-rich savanna in larger leaf size, higher root:shoot ratio, lower grass palatability, greater woody biomass, lower herbaceous water use efficiency and more conspicuous litter layer (Scholes 1990a). In nutrient-poor savanna, woody plant antiherbivore strategy is chemical (tannins, polyphenolics, etc.), whereas it is structural (thorns) in nutrient-rich savanna. Combretaceae and Caesalpiniaceae dominate the former, with Mimosaceae dominating the latter. The soil fauna is high and dominated by termites in nutrient-poor savanna and is low and ant-dominated in nutrient-rich savanna (Scholes 1990a). Both tree and herbaceous layers of nutrient-rich savanna are preferred by kudu over these layers in the nutrient-poor savanna in the Nylsvley Nature Reserve (Owen-Smith 1993). More generally, Owen-Smith (1982) listed 34 large African herbivore species with their preference for either arid/eutrophic or mesic/dystrophic systems; 23 species

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Figure 9.5 *Acacia tenuispina* dominant in the foreground on soil with a very high clay content west of Thabazimbi, between the Crocodile and Marico Rivers (SVcb 1 Dwaalboom Thornveld).

preferred arid/eutrophic (e.g. the browser black rhinoceros and grazer impala), seven preferred mesic/dystrophic (e.g. the browser grey duiker and the grazer buffalo) and four species fell in both categories (e.g. the grazer and browser Cape eland and the grazer tsessebe). The nutrient-poor systems relate to their position on acid crystalline rocks and old erosional surfaces, while the nutrient-rich systems are on fine-grained sediments and young surfaces (Scholes & Scholes 1997). In some special cases the origin of nutrient-rich patches of *Acacia tortilis* embedded within nutrient-poor broad-leaved savanna has been found to be anthropogenic, arising from Iron Age settlements (Blackmore et al. 1990).

There is often an excellent correlation between vegetation patterns and soil types, as exemplified in the KNP (Venter & Gertenbach 1986, Venter et al. 2003). However, there is much floristic variation along rainfall gradients, even with similar substrate such as demonstrated along the Kalahari gradient in Botswana (Ringrose et al. 2003). Even within the broad group of so-called Kalahari sands a variety of soils occur (Van Rooyen 1984) and the proportion of the coarse sand fraction is associated with the occurrence of certain tree species (Moore & Attwell 1999).

Termitaria are a common feature in many savanna types, also throughout many savannas of the world (Josens 1983). On granite-derived soil in the KNP a density of 111 active termite mounds per km^2 has been quoted (Naiman et al. 2003). Termite mounds form islands of significantly elevated nutrient concentrations and are associated with palatable grasses such as *Cenchrus ciliaris* and are heavily used by herbivores, especially in the dry season (Naiman et al. 2003). In the lowveld, Griffioen & O'Connor (1990) found that the percentage clay, pH, conductivity and sodium of the soil of termite mounds were significantly higher than that of the top soils of the adjacent areas. They point out that the elevated pH is at variance with results from some termitaria elsewhere in Africa. Furthermore, they found that *Cenchrus ciliaris* was only associated with termite mounds in the open and did not occur at all on mounds under the canopies of trees. *Panicum maximum* was far more prolific on termite mounds than off the mounds under the canopies of trees. *Heteropogon contortus* does not occur on termite mounds. In a study in the SVs 6 Eastern Valley Bushveld in KwaZulu-Natal (Gower et al. 1992), woody plants were found to be absent around young, active termitaria, and only started to appear once the termitaria began to degenerate and become recolonised by ants or nongrass-harvesting termite species. *Acacia nilotica* was the first to colonise, followed by species such as *Ehretia rigida* and *Maytenus heterophylla*. The older termitaria had bush clumps with a closed canopy including *Ziziphus mucronata*, *Grewia occidentalis*, *Burchellia bubalina*, *Dovyalis zeyheri* and *Cussonia spicata*. Termitaria can serve as a prominent perch for birds with a greatly increased probability for seed to be dispersed on them (Kemp et al. 2003).

Dambos are seasonally waterlogged bottomlands typically embedded within savannas of south-central Africa (Tinley 1982, Von der Heyden 2004). They are often associated with a catenary sequence (Scholes 1997). Although not as frequently encountered in South Africa as in the savannas further north, there are good examples of this kind of catena such as in the Nylsvley Nature Reserve. Here the catena extends from the hydromorphic grassland of the dambo through the yellow-brown sands of the lower slopes to the yellow-red sands of the midslope to the red-brown sands of the upper slope (Von Harmse 1977), a sequence also broadly associated with a plant species gradient (Scholes & Walker 1993). The catenary pattern of sandy uplands to clayey bottomlands is common in parts of the lowveld (Scholes et al. 2001, Venter et al. 2003), where the

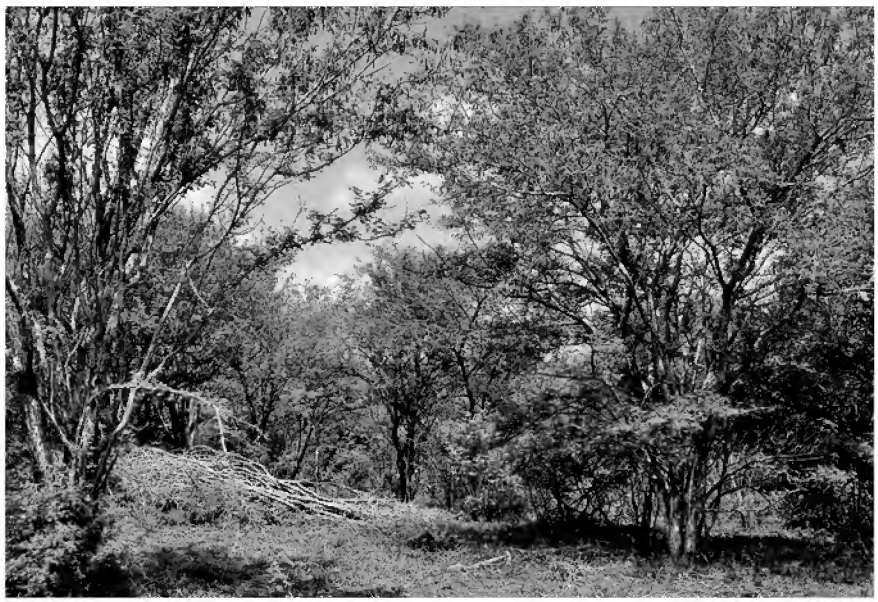

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Figure 9.6 Moderately dense woodland dominated by *Acacia erubescens* on less clayey soils on the Farm Portugal, west of Dwaalboom, Thabazimbi District (SVcb 1 Dwaalboom Thornveld).

catena can include a clear seep zone such as in the Sabi Sand area of the lowveld (see Tinley 1982: Figure 4). Where toplands have been heavily utilised for communal grazing in the lowveld, they become so modified that they classify outside the topland-bottomland dichotomy that characterises this region (Higgens et al. 1999).

Various pattern analyses of plants have been undertaken in southern African savanna vegetation. In the southern Kalahari, both actual and modelled tree spacing tends to be even at small scales, clumped at intermediate scales, and random or clumped at large scales (Jeltsch et al. 1999). Species differences may be important. In a field study in the arid Kalahari, *Acacia erioloba* saplings were found to be aggregated, small trees were randomly or regularly distributed and large trees were randomly spaced. However, in open stands of *A. mellifera* subsp. *detinens* aggregation increased with the size of the shrub (Skarpe 1991b). From a number of sites across a range of conditions on Kalahari sands, Caylor et al. (2003) concluded that small individuals were more aggregated than large ones, and put forward a number of possible mechanisms to explain this pattern. In dystrophic broad-leaved savanna in the Nylsvley Nature Reserve a lack of pattern in the herbaceous layer was attributed mainly to the large number of annual and perennial pioneer and disturbance-indicating species (Theron et al. 1984). Whitaker et al. (1984) concluded that on this site the woody vegetation dominated the pattern. Clearly more studies are needed to elucidate different spatial groupings of plants in the diverse savanna systems.

Roots of savanna plants play a critical role in patterning and function. A well-developed root system allows savanna plants to survive both drought and fire (Menaut 1983). Savanna plants are renowned for their well-developed root systems. A brief summary of the root component and some of its wide variation is given below.

Below-ground plant mass can be considerable. Values such as 29 790 kg ha^{-1} in an area overwhelmingly dominated by small trees of *Colophospermum mopane* are exceptionally high and comparable with that of woodlands elsewhere with much taller trees (Smit & Rethman 1998b). The ratio of below-ground to above-ground parts (root:shoot ratio) in the tall shrub *Ochna pulchra* is still relatively high at a value of about 1 (averaged for the whole population at a site; Rutherford 1982a). Root:shoot ratios of around 5 have been found for shrubby savanna dominated by *Terminalia sericea* (see Rutherford 1982a). The large investment in plant material below ground is believed to be critical for the persistence of the plant under conditions that adversely affect its above-ground parts.

Many savanna woody plants have extensive shallow root systems, but not necessarily to the exclusion of some deeper running roots. The shallow root system enables them to make use of relatively light showers when water does not penetrate far into the ground. The very strongly developed lateral root system can sometimes extend 7–12.5 times that of the canopy radius, and it includes species such as *Terminalia sericea*, *Burkea africana* and *Colophospermum mopane* (Rutherford 1980, 1983, G.N. Smit, personal communication). *Combretum apiculatum* is also reported to have a well-developed shallow lateral root system (Fraser et al. 1987). The high root:shoot ratio and the relatively shallow rooting of *Colophospermum mopane* make it a particularly effective competitor with herbaceous plants (Smit & Rethman 1998b). Some other species have very limited lateral extension such as up to only 1.5 times that of the canopy radius in *Commiphora pyracanthoides* (Jordaan et al. 1998). Contrary to trees of many other savanna systems, this species also has little intergrowth of roots of other tree species. It is also unusual in that, in addition to a tap root system, it has a well-developed fleshy, tuber-like secondary root system that contains a large amount of moisture.

Savanna evergreen trees tend to have deep root systems—at least in dry savanna (Skarpe 1996). *Boscia albitrunca* in the central Kalahari appears to hold the world record for a maximum rooting depth of 68 m (Canadell et al. 1996). In a study in the southern Kalahari dunefield (Gordonia District) Schulze et al. (1998) found downward transport of water in roots (inverse hydraulic lift) with water flow into deeper soil layers. They suggested that inverse hydraulic lift may serve as an important mechanism to facilitate root growth through the dry soil layers underlying the upper profile where precipitation penetrates.

Several low plant species in savanna have stems which are widely interconnected below ground and include geoxylic suffrutices such as *Dichapetalum cymosum*, *Fadogia monticola*, *Lannea edulis*, *Parinari capensis* and *Pygmaeothamnus zeyheri* in the Nylsvley Nature Reserve (Rutherford 1980). In the same reserve several legume species, such as *Elephantorrhiza obliqua* and *Chamaecrista mimosoides*, produce long rhizomes which interconnect widely spaced shoots (Grobbelaar & Rösch 1981); even individuals of *Ochna pulchra* (large shrub, sometimes tree) are sometimes interconnected below ground (Rutherford 1980, 1983).

Leistner (1967) provided an extensive account of the root systems of a wide range of plant species of the southern Kalahari and confirmed that the roots of some species can reach great depths, and that trees can have shallow lateral roots stretching far from the tree. He pointed to several specialist structural features including root sand coats and spongy cortex, succulent roots and contractile roots in monocotyledons and 'deciduous' roots, succulence and wiriness and to suckering in dicotyledons. The ability of plants to sprout from exposed roots is common in species such as *Senna italica* subsp. *arachnoides*, *Heliotropium ciliatum*, *Hermannia tomentosa* and *Lycium hirsutum* and even in adult specimens of *Albizia anthelmintica* (Leistner 1967), and may confer a survival advantage in areas with sometimes unstable sand dunes. Even in deep sandy areas in more humid savanna, the ability of roots to sucker, when exposed and damaged, is very common in *Ochna pulchra* (Rutherford 1983) which, if caused by burrowing animals and small mammals feeding, for example, on soil insects, could result in aerial extension of, and competitive advantage for the plant.

4.2 Plant Interactions

Three major reviews have addressed tree-grass interactions in savannas (Scholes & Archer 1997, Sankaran et al. 2004) or their interaction in the wider context of mixed tree-forb plant systems (House et al. 2003). Here, we emphasise some locally important features of these and other plant interactions that pertain to our region.

Tree-grass mixtures have been regarded as fundamentally unstable, but the simulation models to explore the organisation and dynamics of tree-grass ecosystems are still in their infancy (House et al. 2003). Four classes of hypotheses (models) are recognised for explaining how the woody and herbaceous life forms coexist (House et al. 2003): (1) Niche separation, where woody and herbaceous plants partition resources in space (e.g. preferential access to deep water by woody plants) versus more effective use of shallow soil water by grasses, or in time (e.g. phenological displacement of physiological activity); (2) Balanced composition, where woody and herbaceous plants compete for rather than partition resources, and intraspecific competition (e.g. grass-on-grass and tree-on-tree) dominates over interspecific (e.g. tree on grass) competition; (3) Competitive exclusion,

where the system is driven away from a relatively stable equilibrium and over time the one life form sufficiently pre-empts and monopolises resources so as to virtually eliminate the other. However, disturbances, which have a greater effect on the competitively superior life form, may prevent those plants from achieving or maintaining dominance; (4) Multiple stable states, where the spatial and temporal heterogeneity of resource availability and disturbance is incorporated into equilibrium models so that contrasting tree-grass ratios might exist for a given site at various times. All four the above have elements that should be included (together with many other key factors occurring at various spatial and temporal scales) in a comprehensive model.

By way of example of one of the above, Van Langevelde et al. (2003) suggested the following, based on an interaction between fire and herbivory: an increase in the level of grazing leads to reduced fuel load, which makes fire less intense and, thus, less damaging to trees and, consequently, results in an increase in woody vegetation. The system then switches from a state with trees and grasses to a state with solely trees. Similarly, browsers may enhance the effect of fire on trees because they reduce woody biomass, thus indirectly stimulating grass growth. This consequent increase in fuel load results in a more intense fire and further decline of biomass. The system then switches from a state with solely trees to a state with trees and grasses.

Some locally applied models have shown that rainfall and the competition for water alone were not sufficient to guarantee tree-grass co-existence and to maintain a scattered distribution of Kalahari savanna trees in a cellular automaton model (Jeltsch et al. 1996). In the absence of small-scale heterogeneities (e.g. patches of disturbance), the system is generally driven to a state of either pure grassland or pure woodland. With the introduction of such small-scale heterogeneities, coexistence of trees and grass can occur under a broad range of conditions (Jeltsch et al. 1998). Similarly, Higgins et al. (2000) demonstrated grass-tree coexistence in a model that included fire intensity and its (patchy) variance and its effect on tree recruitment.

The niche separation hypothesis applied locally needs qualification. Contrary to Walker et al. (1981) and Walker & Noy-Meir (1982), grasses do have access to subsoil water, but the two-layer model can still operate, provided each component is the superior competitor in a different layer (Knoop & Walker 1985). Further caution is advised since it has been found that some woody species extract water from a wide range of soil depths, including those near the surface. For instance, whereas *Ochna pulchra* extracts water mostly from above 60 cm depth, extraction of water occurs throughout the whole of the soil profile under *Grewia flavescens* (Moore et al. 1982).

Following an analysis of data from 854 savanna sites across Africa, Sankaran et al. (2005) provide an elegant generalisation of the determinants of co-dominance of trees and grasses in savanna. In savanna with a MAP of less than about 650 mm, water constrains woody cover and permits grasses to exist, while fire, herbivory and soil properties interact to reduce woody cover below the MAP-controlled upper bound. For areas with a MAP above 650 mm, rainfall is sufficient for woody canopy closure, and disturbances (fire, herbivory) are required for the coexistence of trees and grass. They view the latter savanna system as 'unstable'.

Scholes & Archer (1997) suggested that many semi-arid areas on relatively fertile or clayey soils were relatively treeless in pre-colonial times, but were encroached rapidly and apparently irreversibly when grazed continuously by cattle. This is in contrast to semi-arid environments on sandy, low-fertility soils which are seldom treeless. Bush encroachment has long been regarded as a problem for range farmers and wildlife managers (Van der Schijff 1959) and a number of long-term studies have shown a trend for a progressive increase in both tree and shrub cover, e.g. in the Hluhluwe-iMfolozi Park (Watson & Macdonald 1983). Most often woody plant increases have been ascribed to poor land use practices but Bond et al. (2003a) suggested that the general increase in savanna trees in South Africa in more recent times has been assisted by increasing CO_2 concentrations. Ward (2005) contended that causes of bush encroachment are not simple and that bush encroachment, for example, can occur on both heavily grazed areas as well as on areas where grazing is infrequent and light.

The long-term (58 years) increase of woody plant cover on granite substrates and the substantial decline on the basalt substrates in the KNP has been partly ascribed to a difference in competitive intensity of the grasses (Eckhardt et al. 2000). It is thought that the provision of surface water has led to overgrazing of grasses which do not recover rapidly on the granite substrates as opposed to their rapid recovery even after heavy grazing on the relatively nutrient-rich basalts. The sharp decline of woody plant cover on the basalt substrates, however, is more importantly linked to the regular, short-interval prescribed burning over the past 40 years. Bond et al. (2001) demonstrate experimentally at Hluhluwe Game Reserve that both the above-ground and below-ground effects of the herbaceous plants negatively affect both *Acacia nilotica* and *A. theronii*. In Eastern Cape savanna vegetation, removal of the herbaceous layer resulted in an increase in the growth of the *A. karroo* trees illustrating the suppressive effect of the grass-dominated herbaceous layer on woody plants (Stuart-Hill & Tainton 1989). In a broad-leaved nutrient-poor savanna in the Nylsvley Nature Reserve, the effect of the herbaceous vegetation on woody plants was found to be negligible—at least in a period of two years (Knoop & Walker 1985). However, in a nutrient-rich *Acacia* community with seven times more herbaceous biomass, mature woody-plant growth was reduced by the grass-dominated herbaceous layer, especially in a wetter year. Hudak et al. (2003) suggested that soil carbon sequestration may initially increase with bush encroachment, but then it would decline if bush densities become so high that they inhibit understorey grass growth.

There can be major differences in the herbaceous layer under canopies and areas between tree canopies (Scholes & Archer 1997, Smit 2004). Soil nutrient enrichment (N, Ca, K, Mg and Na) and increased soil organic matter is found under trees, especially large ones, due to various mechanisms including leaf litter, stemflow and throughfall of rain and N-fixation under leguminous trees (Smit 2004). In an *Acacia luederitzii*-dominated part of the Kalahari in southern Botswana, significantly higher levels of soil organic carbon and soil organic nitrogen were found under the canopies of the woody vegetation (Feral et al. 2003). Large *A. erioloba* trees in the Kalahari have a close association with animals resting in the shade of the canopy, with the soil enriched with nutrients through faeces, fallen nest material and carcass remains (Dean et al. 1999). In a study in SVk 1 Mafikeng Bushveld near the Molopo, significant development of cyanobacterial soil crusts under the canopies of *A. mellifera* may enable the supply of additional nutrients to the plant (Dougill & Thomas 2004). Despite similar canopy dimensions, soil crust development was found to be greatly reduced under *Grewia flava*, possibly relating to less light reaching the soil surface than with *A. mellifera*. Woody plants can serve as sites of protection for certain grass species, such as for *Themeda triandra* and *Heteropogon contortus* on some heavily grazed areas in the lowveld (O'Connor 1995b).

Acacia karroo trees in the Eastern Cape were found to suppress grass growth up to 9 m away (Stuart-Hill & Tainton 1989). Increasing density of *A. mellifera* individuals strongly depressed herbaceous production in the Molopo area (Rutherford 1978) and grass productivity was strongly inversely related to the LAI of trees in modelling output from the Kalahari (Caylor & Shugart 2004). Scholes (2003) found this a general pattern in savanna where grass declined more steeply per unit increase in tree quantity at low tree cover than at high tree cover. This 'convex relationship' he suggested is explained mainly by the geometry of the spatial interaction between the tree root system and grasses, and the effect of differing phenology (the time course of leaf area exposure) on the acquisition of water and nutrients.

Panicum maximum is a grass commonly associated with under-tree habitats in many South African savanna areas (Griffioen & O'Connor 1990, Smit & Swart 1994, Smit 2004). Tree size is important and *P. maximum* ranged from virtually absent under small trees of *Acacia tortilis*, *A. karroo* and *Dichrostachys cinerea* subsp. *africana* to pure stands under larger trees (Smit & Romburgh 1993). Griffioen & O'Connor (1990) found that *P. maximum* was far more prolific on termite mounds under the canopy of trees. Several species such as *Aristida bipartita* and *Heteropogon contortus* tend to avoid the habitat under the canopy of trees (Griffioen & O'Connor 1990). In some cases the herbaceous species composition under trees in comparison with the open habitat, is not greatly influenced, for example, by the tree layer dominated by *Burkea africana* in the Nylsvley Nature Reserve (Theron et al. 1984), possibly partly relating to the canopy of this species allowing more than 25% light throughfall (Van der Meulen & Werger 1984). Grass species under canopies of woody plants on this site were all C_4 photosynthetic type (Cresswell et al. 1982). However, on the same site, total biomass was significantly greater in the open than under *B. africana* trees while the amount of crude protein was greater under these trees than in the open (Grossman et al. 1980).

Thinning or even total removal of savanna trees is a common practice to counter the apparent suppression of herbaceous plants to improve grazing (Scholes 1990b). However, although thinning of *Colophospermum mopane* confirmed an increase in herbaceous plants, thinning of *Salvadora australis* in the same area appeared to show the reverse on herbaceous plants (Smit 2003b). Scholes's (2003) guideline to thinning suggests that if one needs to keep some trees on the land, the most cost-beneficial pattern of clearing is to remove all the trees in a portion of the landscape, rather than remove a portion of the trees in all of the landscape. In other words, to begin with, the least encroached areas rather than the usual 'intuitive' practice of tackling the most densely treed areas first. This patchy clearing is more easily managed with fire as a clearing mechanism and the dispersal of tree propagules into the cleared area is reduced.

Thinning of *Colophospermum mopane* also reduced inter-tree competition and resulted in a marked increase in the flowering and fruiting of the remaining trees (Smit & Rethman 1998a). Removal of trees closely neighbouring *Acacia nilotica* led to a significant increase of growth when compared with control trees (Smith & Goodman 1986). In bottomland *Acacia* communities in the Pilanesberg Game Reserve, spatial analysis suggested competition among trees as a mechanism controlling their size and density (Smith & Walker 1983). However, of 45 sites spread across the Savanna Biome in South Africa, only at four was the presence of interspecific competition between woody plants indicated (Shackleton 2002). At only 10 of 31 sites tested was intraspecific competition indicated. Despite the limitations of the method used (nearest-neighbour analysis), this does suggest that niche separation between species and within species is generally greater than previously argued. Alternatively, if competition is occurring, its impact is relatively low, both at the level of specific pairs of trees, as well as the community as a whole (Shackleton 2002).

At a site (Vastrap, northeast of Upington) on Kalahari sands, the number of small trees under dominant trees was significantly lower than that expected by chance and is possibly ascribed to limited water supply forcing individuals to disperse away from each other (Caylor et al. 2003). This differed to wetter sites on Kalahari sand in Botswana where the number of small trees under dominant trees was found to be significantly higher than expected. The association with frugivorous birds results in a high frequency of often woody plant species with fleshy fruits (*Boscia*, *Grewia*, *Lycium* and *Solanum*) beneath large trees of *Acacia erioloba* (Dean et al. 1999). Savanna tree species respond differently to shading. Shading reduced survival of *A. tortilis* seedlings in the Nylsvley Nature Reserve (Smith & Shackleton 1988). In the Mkhuze Game Reserve establishment of *A. nilotica* seedlings was restricted to open areas with no woody canopy cover (Smith & Goodman 1987). However, in the same area, seedling establishment of *Euclea divinorum* was limited to areas beneath the canopies of established *Acacia* individuals. *Pappea capensis*, which is widespread in South African savanna, has been shown to perform very poorly in deep shade (Holmes & Cowling 1993). However, in dry years shade may increase moisture availability as evidenced in SVs 7 Bhisho Thornveld where shading dramatically increased survival of seedlings of *A. natalitia* in a drought year (O'Connor 1995a). *Burkea africana* is able to establish under its own canopy and that of some other species (Wilson & Witkowski 2003).

The most commonly observed plant parasites in savanna are mistletoes with a study indicating that mistletoe host preference is negatively correlated with host wood density, which translates in turn to host species preferences (Dzerefos et al. 2003). Thus in lowveld, for example, they found *Sclerocarya birrea* (wood density 560 kg/m^3) was a clearly preferred host species, while *Combretum apiculatum* (wood density 1 230 kg/m^3) was avoided by the woodrose-forming mistletoes *Erianthemum dregei* and *Pedistylis galpinii*. Some species with low wood density were also avoided.

In contrast to the Fynbos, Grassland and Forest Biomes in southern Africa, the most widespread alien invader plants are herbs in the Savanna Biome (Richardson et al. 1997). Most of these are from South America and include *Alternanthera pungens*, *Bidens bipinnata*, *Conyza albida*, *Datura ferox*, *D. stramonium*, *Schkuhria pinnata*, *Solanum elaeagnifolium*, *Tagetes minuta*, *Verbena bonariensis* and *Zinnia peruviana*. Several succulents from the Americas are also important and include *Agave sisalana* and *Cereus jamacaru*. Woody alien invader plants are given in the section on Descriptions of Vegetation Units.

4.3 Rainfall and Temperature Effects

Savanna vegetation structure changes the rainfall that reaches the ground. Studies in areas of the Central Bushveld with a MAP of about 650 mm showed that although the average stemflow of trees per storm was often less than 5% of the gross rainfall; it represented a concentrated application of water to the soil at a point where conditions were ideal for entry (De Villiers 1982). Also interception losses of rainfall are significant and vary mainly between 15% and 20% of the gross rainfall. Stemflow and interception may relate to the sometimes marked ecologi-

cal differences below savanna trees (see section 4.2), but they may also tend to cancel out the net effect of both.

In years of above average rains, savanna deciduous woody species commonly retain their leaves for longer periods, sometimes dropping only a week or two before the new flush of leaves.

Duration of leaf retention into winter as determined by soil moisture is also shown in *Acacia tortilis*. Along a gradient from the Thukela River in midwinter (July) there was 71% leaf retention on the river banks dropping successively to only 10% at 200 m above the river (Milton 1983). A few deciduous savanna woody species characteristically have a particularly long seasonal leaf duration with a very short leafless period (e.g. *Colophospermum mopane*; Dekker & Smit 1996). Many savanna trees produce new leaves before the first rains of the season (Mistry 2000). In some species, the first seasonal activity is flowering, which can start as early as late July in *A. robusta* and *Dombeya rotundifolia*. Slow absorption of water during the leafless period allows for growth to resume before the first rains fall (Van Rooyen et al. 1986). It has also been suggested that the magnitude of shoot growth in a given growth season in certain savanna woody species is influenced by the rainfall of the previous season (Rutherford 1984).

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Figure 9.7 Very low cover of the herbaceous plant layer between and under *Colophospermum mopane* and *Commiphora viminea* trees, east of Pontdrif in Limpopo Province.

In the hyperarid savanna in the southwestern Kalahari periods of drought and the variability of rainfall appear to have a significant influence on herbaceous species in the short term, while there was not much variation in the woody species composition or density (Van Rooyen et al. 1984). In the southern Kalahari after a year of severe drought, Leistner (1967) noted that in contrast to the decimation of all grass species on a particular dune, the survival rate of plants with subterranean storage organs (*Acanthosicyos naudinianus*, *Harpagophytum procumbens* and *Talinum caffrum*) appeared high. Other most obvious survivors were trees and tall shrubs. Herbaceous species composition changed dramatically following a severe drought in savanna of the lowveld east of Acornhoek (O'Connor 1995b). In the Klaserie Nature Reserve after a severe drought, mortality of grasses was very high, but that of woody plants was low (Scholes 1985). Over 80% mortality, for example, was found for *Panicum maximum* and *Schmidtia pappophoroides*. The depauperate state of the herbaceous layer at high densities of *Colophospermum mopane* trees (Figure 9.7) is relatively independent of rainfall (Smit & Rethman 1999).

After some severe drought years in the vicinity of Pontdrif, mortality of *Colophospermum mopane* was most pronounced for individuals less than 1 m tall and with no mortality for individuals taller than 3 m (O'Connor 1998). Dieback of mopane was less on sandier soils in this area (MacGregor & O'Connor 2002). Despite the relatively large leaves of mopane, it is partly protected from desiccation by the oils in its leaves (Venter et al. 2003). In the KNP, after a major drought, 30–40% of mopane were killed in one area while exceptionally high mortality (93%) of *Acacia tortilis* was recorded, but was localised (Viljoen 1995).

In a study replicated in many parts of the KNP, it was found that none of 18 key grass species were lost from the park following the 'severest drought in living memory' (Kennedy et al. 2003). The percentage abundance of these grasses declined during the drought to 87.5% of the pre-drought value. The relative abundance of species such as *Digitaria eriantha* declined while that of *Urochloa mosambicensis* increased, with the latter also spreading to new sites after the drought had past.

Effect of frost on woody savanna plants can be remarkably species-dependent. In the growth season following an unusually cold winter with 11 nights of moderate to heavy frost (–3.5°C measured at 1.5 m above ground: average annual minimum screen temperature of 2.1°C) in SVcb 15 Springbokvlakte Thornveld dominated by *Dichrostachys cinerea* on the Towoomba Research Station, many trees experienced topkill, but with most of these resprouting from the base (Smit 1990). Species significantly damaged by the frost were *D. cinerea*, *Acacia nilotica*, *A. gerrardii* and *A. robusta*. Little affected by the frost were *A. caffra*, *A. karroo*, *A. tortilis*, *Diospyros lycioides*, *Ehretia rigida*, *Grewia flava*, *G. flavescens*, *Rhus leptodictya* and *Ziziphus mucronata*. Of the frost-sensitive *Acacia* species, individuals above a height of 2 m were relatively unaffected by the frost. Smit (1990) observed that fewer of the frost-sensitive species were affected in camps with higher density of woody plants. It was also clear that solitary individuals were damaged more than individuals in groups. Groups of trees taller than 2 m appeared to be more effective in providing protection against frost. Smit (1990) attributed this 'protection' to heat radiated from the earth being reflected downwards by tree canopies. It is perhaps to be expected that almost all the frost-resistant species listed above are distributed farther into colder parts of South Africa than the frost-sensitive species listed.

On Kalahari sand in Hwange National Park in Zimbabwe, strongly species-specific reactions to unusually severe frost were found in a shrubby (height generally 1–2 m) savanna (Rushworth 1975). After frost of –14.4°C measured at ground level (compared to average annual minimum ground temperature of –3.3°C), many woody species experienced 100% (or very close to 100%) death of their main growing stem. These included *Acacia ataxacantha*, *Bauhinia macrantha*, *Burkea africana*, *Combretum collinum*, *C. zeyheri* and *Pterocarpus angolensis*. Data after a different, apparently less severe frost in this area indicated the last two mentioned species to be particularly susceptible to such frost. *A. fleckii*, *Terminalia sericea* and *Ochna pulchra* were remarkably resistant to even the more severe frost.

Individuals damaged by frost usually produced multiple coppice stems following the event.

4.4 Fire

The strong seasonality of rainfall in southern African savanna allows for plant material produced in the wet season to dry and be burned during the dry season. Fire has undoubtedly been an important factor in savanna ever since the ascension of the grass layer to dominance. Fire has long be regarded as a tool for directly influencing the woody plant components of savanna. As a management tool, a popular view is that in the moist savannas fire *per se* can be used to control bush encroachment, whereas in the arid savannas fire has the role of maintaining trees and shrubs at an available height and in an acceptable state for browsing animals (Trollope 1980).

Biomass burning is an important ecosystem process in southern Africa, also with significant implications for regional and global atmospheric chemistry and biogeochemical cycles. Fire is a significant source of trace gases and aerosols from savannas (Korontzi et al. 2003). The seasonal tropospheric ozone enhancement is a result of biomass burning (Scholes & Andreae 2000). At a local level, fire oxidizes organically bound elements in the vegetation and litter and releases them in forms available to plants. Elements that are not volatilised, are added to the soil, but such nutrient increases are usually limited to the surface layers of the soil and after an initial peak, concentration may decline rapidly (Frost & Robertson 1987). Nitrogen loss by fire in the KNP is replenished in burned areas, but the mechanisms by which this is achieved are unclear (Aranibar et al. 2003). In southern Africa, the main fuel is dry grass which burns with high efficiency and produces relatively low emissions of methane, carbon monoxide and aerosols per unit mass of fuel consumed (Scholes et al. 1996).

Studies show that the effect of fires on savanna plants can be highly variable. A study on the effects of fire on populations of *Sclerocarya birrea* in the lowveld showed that although the lower individuals (<2 m tall) were greatly affected by fire, density was unaffected (Jacobs & Biggs 2001). In savanna dominated by *Dichrostachys cinerea* and *Acacia gerrardii* in the Central Bushveld, height of trees less than 3 m was reduced due to severe topkill, but trees higher than 3 m were unaffected by the fire (Jordaan 1995). A very hot fire in *Acacia nigrescens–Combretum apiculatum* in eastern Botswana resulted in topkill of all plants below a height of 2 m and declining degrees of partial topkill with increasing heights (Sweet & Tacheba 1985). Almost all the plants that suffered complete above-ground kill exhibited basal coppice, as did many of those showing only partial topkill. In the Nylsvley Nature Reserve, mortality (total kill) of woody plants after fire was very low and where this occurred often involved plants lower than 25 cm tall (Rutherford 1981). *Grewia flavescens* has one of the highest fuel loads within the plant canopy and many plants are completely consumed by fire yet no mortality was found after fire. Mortality of *Ochna pulchra* was higher (5%) in a faster burn than in a slower burn (1%), where the latter type of fire allows for greater concentration of heat nearer the ground. *A. karroo* is hardly affected by back fires in the Eastern Cape despite the concentration of heat closer to the ground in contrast to that in head fires which cause significant topkill of trees up to a height of 3 m (Trollope 1984). Bond (1997) suggested that the occasional killing of large savanna trees through fire relates to the loss of the insulating properties of their bark.

Average shrub and tree mortality of only 1.3% has been quoted for 43 fires across a broad range of savanna areas in the KNP (Shea et al. 1996). By contrast, in hyperarid savanna of the southwestern Kalahari, where fire occurs infrequently usually after periods of exceptionally high rainfall, a fire killed approximately one third of *Acacia erioloba* trees, with most extensive damage occurring amongst fully grown trees (Van der Walt & Le Riche 1984).

Fire does not necessarily affect production of the grass layer (Grossman et al. 1981). However, grass species may respond differently to fire. In the Nylsvley Nature Reserve, a long-term study indicated that fire resulted in a basal area reduction of *Eragrostis pallens*, an increase of *Heteropogon contortus*, but had no effect on *Digitaria eriantha* (Van Rooyen et al. 1993). Annual burning combined with the effect of fire on soil moisture availability keeps the individual grass plants small, leaving space for the colonisation of opportunistic species such as *Melinis repens*, *Schizachyrium jeffreysii*, *Pogonarthria squarrosa*, *Aristida mollissima* subsp. *argentea*, *A. stipitata* and *A. congesta* (Yeaton et al. 1988).

Exclusion of fire was found to lead to increased biomass of woody plants such as *Acacia nilotica* in the Hluhluwe Game Reserve (Skowno et al. 1999). The large increase in *Dichrostachys cinerea* in Hlane National Park, Swaziland, is due to restricted occurrence of fire (Roques 2004). Possibly related to this is that this park also has an unusual age structure of *A. nigrescens*—the only species above 6 m height in the area (Gertenbach & Potgieter 1978). Using a Dynamic Global Vegetation Model (DGVM), simulations suggest that most of the eastern half of South Africa could support much higher tree cover without fire (Bond et al. 2003b). Savanna in areas with a MAP below 650 mm showed a less compelling trend to woodiness.

The effects of fire on vegetation is very much a function of the behaviour and characteristics of the fire. The intensity and duration of the dry winter season and the frost period (where applicable) determine the degree of inflammability (Edwards 1984). Co-occurrence of independent episodic events, for example a severe late frost coinciding with a high grass fuel load, and followed by a dry summer can result in exceptionally intense fires as occurred in southern Africa in 1968/9 (Walker 1985). The degree of combustion of plant fuels is greater during back fires as compared to head fires (Trollope et al. 1996). However, behaviour of head fires may be more variable than that of back fires, with a greater range in fire intensity in the former (Trollope et al. 1996). Combustion efficiency in savanna was found to be mainly determined by the interaction between the standing grass and litter (see Ward et al. 1996). Fireline intensities and flame lengths were regarded as the best descriptors of the degree of topkill of savanna trees and shrubs (Van Wilgen & Willis 1988). Higher frequency fires on the drier soils in the shrub mopane areas of the KNP had a detrimental effect on the herbaceous vegetation (Gertenbach & Potgieter 1979).

Mean fire return period during wet phases was found to be less than for dry phases in the Hluhluwe-iMfolozi Park (Balfour & Howison 2001). There is a direct positive relationship between grass biomass and probability of fire (Van Wilgen et al. 2003). Lightning fires tend to start at the start of the wet season, during October and November, while anthropogenic fires are usually started during the dry season, between July and August. A long-term study in the *Colophospermum mopane*-dominated Mooiplaas area of the KNP showed that compared to the vegetation with the early-wet season fires, the mid-dry season fires yield a shorter, more scrubby and coppiced savanna (Kennedy & Potgieter 2003). This might be ascribed to fires that occur during the mid-dry season being likely to burn hotter than fires that occur in the early-wet season when the grass layer has

been dampened by the early spring rains, and when there is the possible presence of some new green growth.

Some plants avoid fire by being associated with generally fire-protected habitats in savanna. Examples of such habitats include rocky outcrops (*Cussonia natalensis*), termitaria (*Diospyros mespiliformis*, *Schotia brachypetala*, *Mimusops zeyheri*) and bush clumps (*Ehretia rigida*, *D. lycioides*; Frost 1985b).

Three candidate approaches to fire management have been put forward in the KNP: a lightning fire (letting nature take its course) approach; a patch mosaic burning approach which aims to establish a mosaic of vegetation structure types; and an approach based on the assessment of grass biomass and the species composition of the grass sward. Van Wilgen et al. (1998) compared the advantages and disadvantages of these approaches. A patch-mosaic system of burning is based on the premise that fire pattern is a surrogate for diversity, producing a range of patches in the landscape with unique patch characteristics and fire histories (Parr & Brockett 1999).

4.5 Vegetation-animal Interactions

4.5.1 Impact of Animals

The savannas of Africa are occupied by the earth's richest and most spectacular large mammal fauna. This fauna was even richer in the distant past and it is reasonable to expect that these large animals have long influenced the plants on which they feed and through them the form of the savannas (Cumming 1982, Sinclair 1983). The African Savanna Biome includes more extant ungulate species than any other continent (Du Toit 2003). However, even termites can be the main herbivore resulting in decline of plant cover in places of the lowveld with fairly dense cover of *Grewia bicolor* and *Dichrostachys cinerea* and a relatively low density of herbivores (Braack 1995). In the Nylsvley Nature Reserve, of the annual herbaceous layer production, grasshoppers were estimated to remove over a third of that utilised by all herbivore species (which included a herd of cattle) on the site (Gandar 1982). On occasion lepidopteral outbreaks and subsequent herbivory can result in trees having to replace up to 75% of their leaf biomass in a single season (Frost 1985a).

The dependence of animals on plants has many wide-ranging effects on the plants and vegetation in savanna. O'Connor (1996) reviewed the consequences of browsing of savanna woody plants by ungulates for their physiological functioning, growth, and demographic processes. Many effects are of a generalist nature, i.e. not discriminating between different plants within a given functional guild. Many other effects are species-specific, for instance the dependence of gall-forming insects on a very limited range of plant species in South African savanna (Veltman & McGeoch 2003). Grazers can be bulk grazers, that is, they do not exercise a high degree of selective grazing (for example buffalo and domestic cattle), or can be concentrate grazers which are generally small grazing animals (such as impala and domestic sheep), with very selective grazing (Trollope 1990). However, large herbivores can also avoid certain plants, e.g. *Combretum apiculatum* is not utilised by black rhino in the Ithala Game Reserve (Kotze & Zacharias 1993). Giraffe can have dramatically different effects within the same genus of tree in the Ithala Game Reserve (Bond & Loffell 2001). Populations of *Acacia davyi* have become extinct in areas accessible to giraffe following their introduction some 20 years earlier. By contrast, *A. tortilis* showed no or very low mortality attributable to giraffe browsing. Food preferences can change with season, as was found in the North-West Province. *Ziziphus mucronata* and *Peltophorum africanum* were important food plants for giraffe during the wet season as opposed to *A. tortilis* and *C. hereroense* during the dry season (Sauer et al. 1977). There is a tendency to widen the dietary acceptance range as the overall abundance of favoured food species declines (Owen-Smith 1982). Domestic herbivores are less mobile than many wild species, impeding large-scale selectivity, and are kept at less variable and usually higher densities, preventing small-scale selectivity (Skarpe 1991a).

Elephant have the potential to literally shape African savannas. Savanna woodlands have been changed to wooded grasslands, bushed grasslands or even grasslands in many parts of eastern, central and southern Africa by the activities of elephant (Cumming 1982). Damage by elephants broadly takes three forms: the tearing of leaves and branches, the stripping of bark from the main stem, and the pushing over of an entire tree (Scholes et al. 2003). Elephants clearly affect woody plant population structures. This is dramatically visible, for example, where there are few large trees outside an elephant-proof exclosure in the KNP and a more even spread woody plant structure inside the exclosure without elephant (Trollope et al. 1998). Studies in savanna in western Zimbabwe show that tree species associated with sandy soils are less preferred by elephants than species on more fertile soils such as those associated with termite mounds (Holdo 2003). *Acacia nigrescens* is the tree species most affected by ringbarking by elephant in Hlane Royal National Park in Swaziland (Bowen 2004). In the northern KNP, ringbarking of *A. nigrescens* is more than twice as prevalent than pushing over these trees (Engelbrecht 1979). The pushing over of *A. nigrescens* trees is almost exclusively limited to young adult trees (with shallow root systems). Elephant impact on *Sclerocarya birrea* decreases with distance from roads, with the zone of high impact 10 m from roads and relatively low impact beyond 50 m from roads (Coetzee et al. 1979). Substantially higher impact also occurs along the boundaries of populations of *Sclerocarya birrea*. Utilisation is often highly selective, as for example in the Songimvelo Game Reserve near Barberton, where *Cussonia spicata* and *Pterocarpus angolensis*, despite being less common than other species present, are much selected by elephant (Steyn & Stalmans 2001). In the Sabi Sand Reserve, significantly higher levels of N, Na and Mg were found in the cambium of the species most regularly bark-stripped by elephant (Hiscocks 1999). Some species showed a high level of resilience to elephants, with one study indicating that all elephant-damaged trees survived in an area of the lowveld (Botha et al. 2002).

Using an experimental approach, Capon & O'Connor (1990) showed that predation of grass seed by ants and rodents in lowveld savanna was high and could potentially decimate the input of fresh seed. They suggest that predation is one of the major processes responsible for the well-recorded poor correlation between the abundance of certain perennial grasses (with large seeds) in the vegetation and their virtual absence from the seed bank.

There have been numerous studies in southern African savanna on the nature of the piosphere effect where animals trample and utilise vegetation in the vicinity of water points (Figure 9.8). Introduction of artificial water points in the arid Kalahari, where in earlier times there had only been a few natural water points, has been a concern for multiplying the number of areas of vegetation damaged around water points (Palmer & Van Rooyen 1998). Water points in the Kalahari create trampling gradients where a model indicates negligible recovery even after 100 years after withdrawal of cattle (Jeltsch et al. 1997a). There is an almost complete lack of woody plants in the vicinity of artificial watering points ('sacrifice area') on Satara basaltic soils with

a zone of high utilisation of woody vegetation extending far beyond this area (Brits et al. 2002). Impact around such dams can be species-specific with, for example, more annual grass species with increasing impact (Thrash et al. 1993). Amongst dominant woody plants *Combretum apiculatum* was more sensitive to these impacts than *Colophospermum mopane* (Thrash et al. 1991b), but the woody stratum as a whole was less sensitive to the effect of the dam than the basal cover of the herbaceous stratum (Thrash et al. 1991a). Based on a study on the Klaserie Nature Reserve, Parker & Witkowski (1999) found greater impact on herbaceous plants around seasonal water points than around perennial water points, suggesting preferential utilisation of ephemeral surface water by herbivores during the wet season. In the KNP, borehole closure led to an increase in the relative abundance of decreased grass species, suggesting that here the piosphere effects on herbaceous community composition may be reversible (Gaylard et al. 2003). Around water points in an area of SVk 4 Kimberley Thornveld near Barkly West, change in bare ground and vegetation height within the diminishing grazing gradient was discernible up to 75 m from the water point (Smet & Ward 2005). Abundance of *Schmidtia pappophoroides* increased from very low near the water point and stabilised at about 200 m from the water point. Up to 50 m from a goat kraal in the Thukela Valley, extensive browsing by Boer goats resulted in great mortality of the succulent *Aloe ferox*, with small plants being the most heavily utilised (Breebaart et al. 2002).

Different and complex impact gradients can occur around rural human settlements both as a combination of the effects of local domestic animal stock and use of other resources by people around the settlement. Around rural settlements in the lowveld, at distances up to 450 to 3 100 m from the periphery of the village, woody vegetation decreased (at different amounts according to species), but herbaceous cover increased (Shackleton et al. 1994). Wood is the primary domestic energy source in these settlements.

Grazing pressure elsewhere often has predictable results, but not always. The ratio of unpalatable to palatable grasses depends on the level of grazing pressure and whether this level has been increasing or decreasing (a hysteresis effect with a higher ratio if decreasing for the same given level of grazing pressure; Walker 1987). Shrub encroachment was found to occur in the southern Kalahari by simulating cattle grazing beyond a threshold pressure under all rainfall scenarios (Jeltsch et al.1997b, Weber et al. 1998). Low grazing pressure (33 ha lsu^{-1}) had no effect on shrub cover and distribution. But increasing the grazing pressure to 22 ha lsu^{-1} led to a continuous increase in shrub cover. Reduced grass competition, combined with some years of relatively high rainfall, favour shrub establishment. In arid Kalahari savanna, *Acacia mellifera* shows the greatest increase in response to overgrazing (Skarpe 1990). Woody species richness does not appear to be sensitive to different stocking rates by game and cattle as shown at a wide range of sites in Zimbabwean savannas (Richardson-Kageler 2003). In a lowveld herbaceous sward, the proportion of annuals was highest in communal cattle lands and the proportion of perennial species highest on commercial game farms (Parsons et al. 1997). Communal management appears to markedly reduce densities of most tree species (Shackleton 1993).

4.5.2 *Plant Response Types and Features*

Savanna woody plants have a range of deterrents to browsing. Secondary compounds can be digestibility-reducing, mostly tannins, or contain toxic substances which interfere directly with the physiology of the consumer (e.g. alkaloids, amines; Owen-Smith 1982). Sensitivity can vary according to animal type. For example, in *Burkea* savanna, cattle are susceptible to monofluoracetate poisoning from ingestion of the leaves of *Dichapetalum cymosum* in spring, but wild ungulates seem unaffected (Owen-Smith 1982). Structural repellents such as thorns, spines or twiggy growth form, usually found in plants with highly nutritious foliage, do not prevent feeding on such plants by browsers such as kudu and giraffe, but could affect relative preferences through their influence on bite sizes and biting rates (Owen-Smith 1982). *Acacia mellifera*, with its strong hook thorns, is a preferred food species by black rhinoceros who bite off shoots up to a thickness of 10 mm, with thorns appearing in the dung (Joubert & Eloff 1971). Also kudu, under dry season conditions of food shortage, have been observed eating thorny *Acacia* twig ends (Owen-Smith 1985). Grasses have also evolved grazing deterrents (Stuart-Hill & Mentis 1982). Chemical protection is found in such species as *Bothriochloa insculpta* and *Elionurus muticus*. Physical protection is conferred, for example in *Aristida junciformis*, by the high breaking tension of its leaves which makes it difficult for herbivores to break off the leaves. *Setaria sphacelata* has hairy leaves which collect dust, rendering them unacceptable to the animal.

L. Mucina

Figure 9.8 The piosphere effect around a drinking hole (Kumana Dam, north of Tshokwane) in the Kruger National Park. The piosphere extends well beyond the visibly impacted terrain nearest the water.

As with their response to fire, many savanna plants recover well after removal of plant material (without the heat of fire) and appear to occupy a long-lasting persistence niche. A wide range of woody plants of savannas exhibit a strong coppicing ability following cutting (Shackleton 2000a, Smit 2003a). The longevity of savanna tree species explains the lag between heavy utilisation and species loss (Higgins et al. 1999). It has also been found in the Bushbuckridge part of the lowveld that the taller the potential height of a species, the fewer were the coppice shoots per stump surface area (Shackleton 2000a). *Acacia tortilis* trees in the Central Bushveld were tolerant of damage and continued

to increase in size even when all the current season's shoots were removed (Milton 1988). Coppicing of *Colophospermum mopane* trees from the main stem ('hedging') when broken by elephant, provides these animals with an increased availability of preferred size range of branches of this preferred food species (Smallie & O'Connor 2000). Productivity of woody plants and browse production are reviewed by Smit et al. (1996) and are not repeated here. Many grasses are tolerant of grazing, for instance through tillering. Tillering after removal of the apex of the parent tiller stimulates profuse vegetative reproduction, for example in *Themeda triandra* (Stuart-Hill & Mentis 1982).

Plant species have been classified according to their response to grazing which is in turn used to determine a veld condition score for veld condition assessment. The classification results in various forms of increaser and decreaser plant species. We look at an example of one such classification system. Van Rooyen et al. (1991) recognise five response types with examples from southern Kalahari savanna. (1) Species characteristic of under-utilised veld which decrease in frequency along the grazing gradient. These are usually absent from veld that is moderately to over-grazed (Decreaser species). An example is *Aristida meridionalis*. (2) Species rare or low in frequency in under-utilised veld, but which increase when the veld is lightly grazed. Moderate to heavy grazing decreases their numbers (Intermediate 1 species). An example is *Centropodia glauca*. (3) Species that rarely occur in lightly grazed veld but that increase in frequency when the veld is moderately or selectively grazed (Intermediate 2 species). An example is *Stipagrostis amabilis*. (4) Species that are rare in light to moderately grazed veld but that increase when the veld is fairly heavily grazed (Increaser species). An example is *Schmidtia kalahariensis*. (5) Species that are absent in lightly grazed veld but that become dominant in severely overgrazed veld (Encroacher species). An example is *Chamaesyce inaequilatera*. Van Rooyen et al. (1991) provide useful graphical representations of these five categories with many examples. The concept of decreaser and increaser plant categories has been applied in many other savanna areas (e.g. indicator species for Nylsvley Nature Reserve; Dörgeloh 1999a), also being related to preferred grazing areas (Wentzel et al. 1991).

There are of course also clear-cut benefits of animals to plants. The dependence of plants on animals includes pollinators. For instance in the KNP, honey bees are regarded as key pollinators without which many plant species would be dramatically reduced in abundance and distribution, if not become extinct (Braack & Kryger 2003). In contrast, fig wasps have an extraordinarily narrow and interdependent relationship with fig species (Naiman et al. 2003). Even giraffe are regarded as a pollinator of *Acacia nigrescens* potentially effective through a home range of more than 250 km^2 (Naiman et al. 2003). Dispersal of seeds of some species is effected by birds (Naiman et al. 2003). Mistletoes have a close relationship with birds, depending on them for pollination and for dispersal to suitable establishment sites on host trees (Kemp et al. 2003). Although the floras of the Kalahari savanna are considered to be mainly wind-dispersed, endozoochory is a primary or secondary dispersal mechanism in many plants (Milton & Dean 2001).

4.6 Management

Various tools have been developed to manage savanna, including a decision analysis approach (Norton & Walker 1985), range condition and grazing capacity assessment models (Steenekamp & Bosch 1995), and many others. To various degrees, these tools take into account the relations between trees and grass, tree and tree, animal and plant, and other issues described in the previous sections. However, they usually must add economic and logistical factors for practical application. There is also a bid to account for farming with game in developing these tools. There has been a great increase in game farming in South Africa in recent years following the earlier debates about the extent to which the increase in grass growth after bush clearing offsets the loss in edible and available browse (Walker 1976). Less commonly incorporated as an integrative tool are restoration interventions. Smit (2004) advocates that any restoration programme in savanna (chemical, mechanical or biological) of areas encroached by woody plants should focus on tree thinning rather than on clearing of all woody plants (but see Scholes 2003, section 4.2). It is important to achieve a balanced compromise between the reduction of the competitive effect of the trees on the herbaceous layer and the preservation of the positive influences that the trees may have, but there are divergent views on how to achieve this.

Barnes (1982) summarised various management options for utilisation of savanna in southern Africa for maximising animal production. These include intensifying secondary production through modification of the ecosystem so as to ensure the presence of the most desirable plants, and to create, within the limitations of the local environment, optimal conditions for plant growth. This includes the manipulation of the herbivore population for more efficient utilisation of the vegetation. Matching the animal population and the food supply includes consideration of multispecies herbivore populations or mixing domestic and wild ungulates. Introduction of selected pasture legumes in the herbaceous layer (as opposed to application of fertiliser) is likely to be successful only in higher-rainfall areas of savanna and is obviously one of the management options least compatible with nature conservation objectives. Control of animal distribution and management of grazing involves matters such as drinking water supplies, the feeding of supplements, and consideration of grazing management systems, including rotational grazing. Hadley (1985) gave an overview of resource management in savanna environments, including social perspectives. For further discussion of management issues, often on a biome basis, see extensive contributions by Tainton (1999).

In a situation very different from that of wishing to maximise animal production, the KNP has relatively recently adopted a system of adaptive ecosystem management (Strategic Adaptive Management; Biggs & Rogers 2003). This system embraces spatiotemporal heterogeneity and includes the concept of Thresholds of Potential Concern (TPCs), a set of operational goals that together define the spatiotemporal heterogeneity conditions for which the KNP ecosystem is managed. TPCs are defined as upper and lower levels along a continuum of change in selected environmental indicators. When this level is reached, or is predicted will be reached, it prompts an assessment of the causes of the change and forms a basis for deciding whether management action is needed to moderate the change. Policy has also recently shifted towards burning under diverse rather than fixed conditions (Van Wilgen et al. 2003). Patch mosaic burning is the current view as opposed to the previous quasi-agricultural block burning in KNP (Biggs 2003). Elephants with their possible ultimate 'major simplification of habitats' make management of elephant numbers a major topic of debate in wildlife systems (Whyte et al. 2003).

5. Conservation

There has been a substantial loss of savanna area due to cultivation, more so than other transformational land use practices. Most of the agricultural expansion took place before the 1960s, especially in the wetter eastern parts of the country (Biggs & Scholes 2002). Impacts have been analysed by various sources

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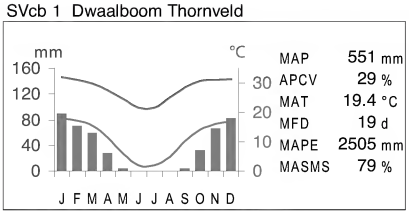
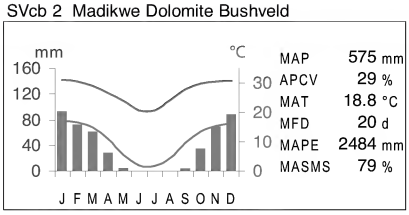
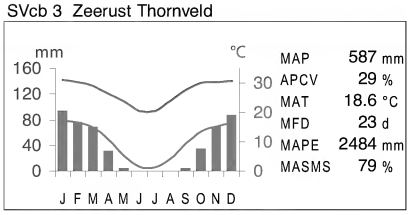


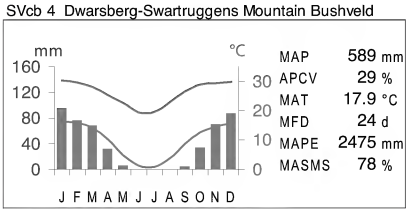
SVcb 2 Madikwe Dolomite Bushveld



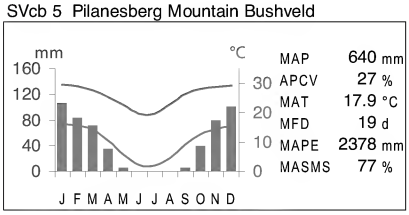
SVcb 3 Zeerust Thornveld



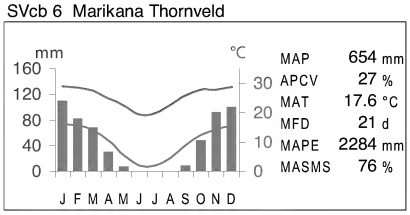
SVcb 4 Dwarsberg-Swartruggens Mountain Bushveld



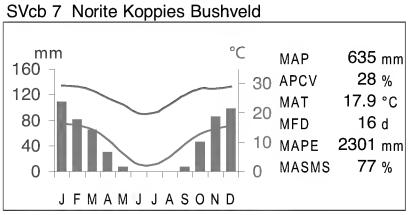
SVcb 5 Pilanesberg Mountain Bushveld



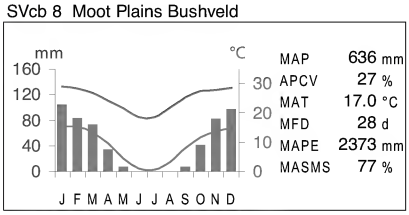
SVcb 6 Marikana Thornveld



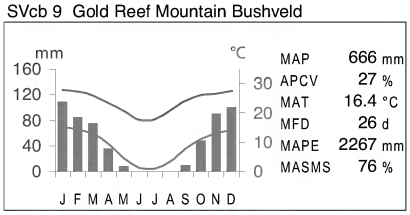
SVcb 7 Norite Koppies Bushveld



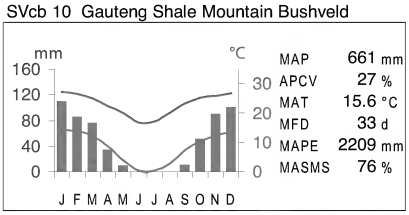
SVcb 8 Moot Plains Bushveld



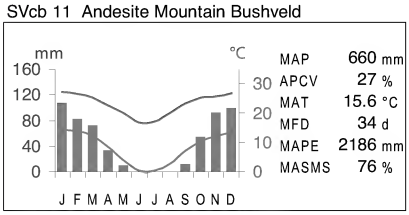
SVcb 9 Gold Reef Mountain Bushveld



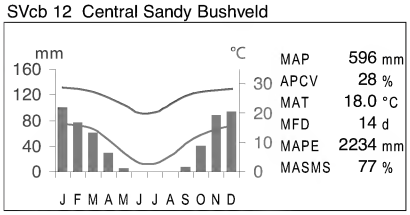
SVcb 10 Gauteng Shale Mountain Bushveld



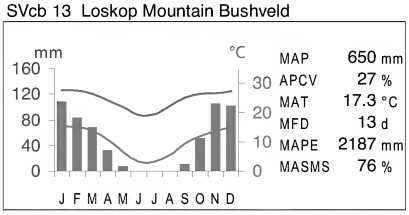
SVcb 11 Andesite Mountain Bushveld



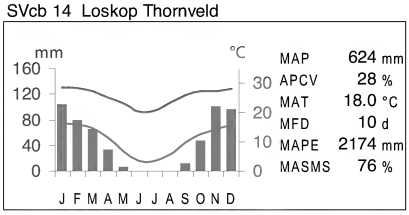
SVcb 12 Central Sandy Bushveld



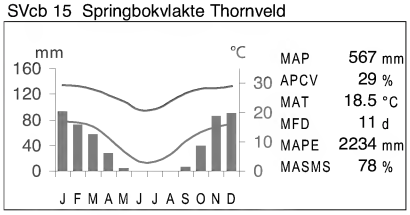
SVcb 13 Loskop Mountain Bushveld



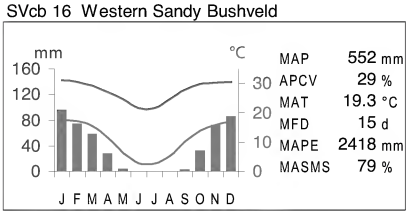
SVcb 14 Loskop Thornveld



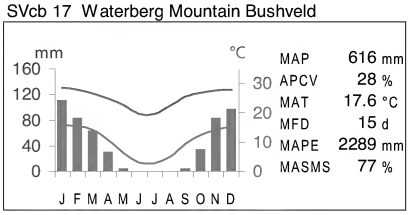
SVcb 15 Springbokvlakte Thornveld



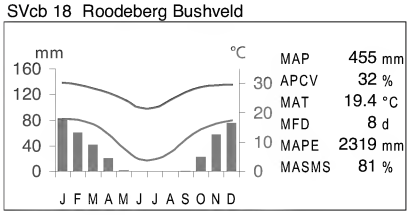
SVcb 16 Western Sandy Bushveld



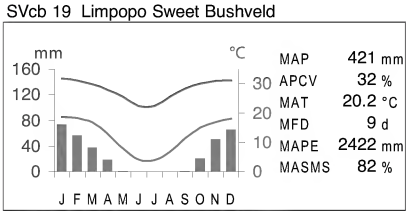
SVcb 17 Waterberg Mountain Bushveld



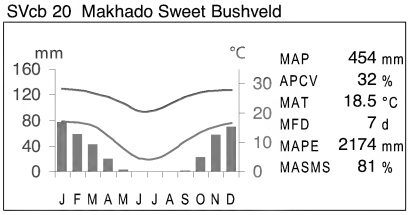
SVcb 18 Roodeberg Bushveld



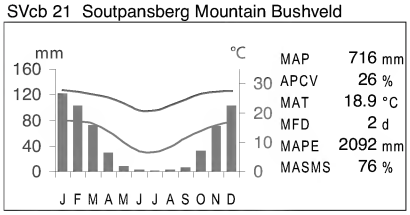
SVcb 19 Limpopo Sweet Bushveld



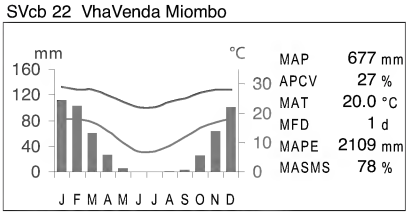
SVcb 20 Makhado Sweet Bushveld



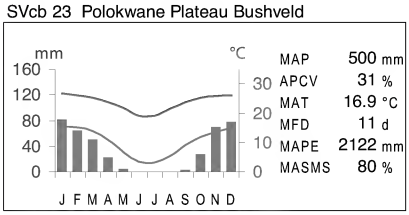
SVcb 21 Soutpansberg Mountain Bushveld



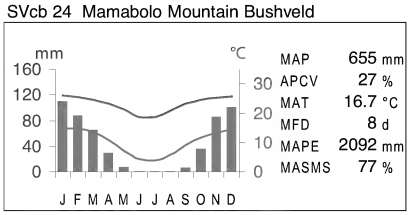
SVcb 22 VhaVenda Miombo



SVcb 23 Polokwane Plateau Bushveld



SVcb 24 Mamabolo Mountain Bushveld



that include the savanna areas (e.g. Thompson et al. 2001). Many aspects relating to conservation in savanna are expanded upon by Huntley (1989) and by Rebelo (1997), and it is clear that substantial progress has been made (also more recently) since the consideration of the state of nature conservation in southern Africa at a meeting held in Skukuza in 1976 (De Graaff & Van der Walt 1977).

Wessels et al. (2003) identified potential conflict areas between land transformation and biodiversity conservation in the north-eastern part of South Africa. This transformation deals with the change from natural vegetation to other land uses, such as crop cultivation and urban development. The analysis included the Lowveld and Mopane Savannas as well as most of the Central Bushveld and Sub-Escarpment Savannas. Potential future agricultural conflict areas include the Waterberg–Dwaalboom–Thabazimbi area where particularly within the valleys of the Waterberg (northern part of SVcb 12 Central Sandy Bushveld) there could be a threat to a unique area of significant conservation importance.

Climate change has been predicted to reduce the area of the Grassland Biome at the cost of expanding savanna vegetation in the northern and eastern sectors (Ellery et al. 1991). Three climate change scenarios (developed from GCMs and modelling a doubling of atmospheric CO_2 concentration) applied to South Africa (Rutherford et al. 1999a) indicated that the Savanna Biome might be less severely impacted than some other biomes further west. Kalahari is possibly the most vulnerable area. Individual species are likely to respond differently and it is possible that *Colophospermum mopane* might expand southwards in the lowveld into newly climatically suitable areas under projected climate change. Rutherford et al. (1999b) assigned the relative vulnerability of individual plant species of two national parks in the Savanna Biome to climate change. The number of species at risk of extinction in the Kgalagadi Transfrontier Park was marginally greater than that in the Vaalbos National Park.

Many plant species are specifically targeted by local communities for a wide range of uses not only for human application, but also for applying to livestock. For example, in a communal area in northern KwaZulu-Natal, farmers use *Cissus quadrangularis* for treating worm infestations and coughs, and *Sarcostemma viminale* for increasing milk production in their livestock (Kunene et al. 2003). Less abundant targeted species are obviously at risk of local extinction with sustained pressure of utilisation.

Alien plant species continue to pose a threat to areas of savanna although in areas such as the KNP (outside riverine habitats) this is sometimes localised, for instance along road verges (Freitag-Ronaldson & Foxcroft 2003). Indigenous woodland in the Kalahari has been found to support a significantly higher diversity of bird species than areas invaded by alien *Prosopis* species (Dean et al. 2002), confirming the conservational need for control of alien species. Threats are usually relative and can (sometimes correctly) divert resources for remedial action. In the Hluhluwe-iMfolozi Park in KwaZulu-Natal, the savanna was reported as less threatened than the adjacent riverine and forest-edge habitats (Macdonald 1983).

Research has included studies that point to specific actions, for example showing that cleared patches covered with grass litter experience the greatest colonisation of grasses (O'Connor 1991). More such explicit results are needed for rehabilitation programmes. But overall, there is a need to reach conservation goals more quickly to minimise losses in biodiversity (Reyers 2004).

For further information relating to conservation in savanna, see the chapters on Ecosystem Status and on Vulnerability of Vegetation Types in this book.

6. Further Research

Although there have been several earlier regional floristic accounts of savanna vegetation (e.g. Van der Schijff 1971, Van der Meulen 1978, Van der Meulen & Westfall 1979) and numerous more detailed surveys given in the references to the descriptions of each vegetation unit, the coverage is still very incomplete. Analysis of diversity patterns is, surprisingly, still in its infancy in savanna. Studies on demography of African savanna grasses are scant (O'Connor 1994), as for other savanna plant forms. Investigation of the full implications of the persistence niche of woody plants in savanna has barely started. We still have no idea of the true age structures of populations of such plants as opposed to the potentially misleading analyses of age (actually size) distributions based on above-ground plant parts only. A comprehensive model that explains both coexistence and the relative productivity of the tree and grass components across the diverse savannas of the world has yet to emerge (Sankaran et al. 2004).

As with many endeavours within the natural sciences, there is a clear need to integrate social and economic spheres into our current biophysical thinking (Biggs 2003) to ensure viable and sustainable systems of biodiversity and their associated ecosystem services in savannas.

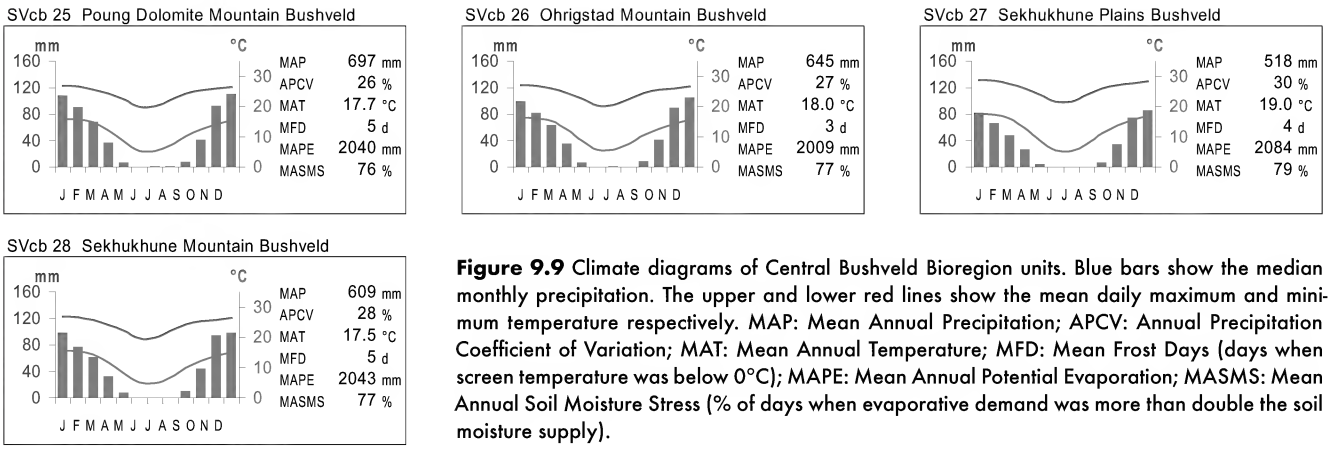


Figure 9.9 Climate diagrams of Central Bushveld Bioregion units. Blue bars show the median monthly precipitation. The upper and lower red lines show the mean daily maximum and minimum temperature respectively. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days (days when screen temperature was below 0°C); MAPE: Mean Annual Potential Evaporation; MASMS: Mean Annual Soil Moisture Stress (% of days when evaporative demand was more than double the soil moisture supply).

7. Descriptions of Vegetation Units

Central Bushveld

SVcb 1 Dwaalboom Thornveld

VT 13 Other Turf Thornveld (58%) (Acocks 1953). LR 14 Clay Thorn Bushveld (48%), LR 18 Mixed Bushveld (43%) (Low & Rebelo 1996).

Distribution Limpopo and North-West Provinces: Flats north of the Dwarsberge and associated ridges mainly west of the Crocodile River in the Dwaalboom area but including a patch around Sentrum. South of the ridges it extends eastwards from the Nietverdiend area, north of the Pilanesberg to the Northam area. Altitude 900–1 200 m.

Vegetation & Landscape Features Plains with layer of scattered, low to medium high, deciduous microphyllous trees and shrubs with a few broad-leaved tree species, and an almost continuous herbaceous layer dominated by grass species. *Acacia tortilis* and *A. nilotica* dominate on the medium clays (at least 21% clay in the upper soil horizon but high in the lower horizons; Figure 9.10). On particularly heavy clays (>55% clay in all horizons) most other woody plants are excluded and the diminutive *A. tenuispina* dominates at a height of less than 1 m above ground (Figure 9.5). On the sandy clay loam soils (with not more than 35% clay in the upper horizon but high in the lower horizons) *A. erubescens* is the most prominent tree (Pauw 1988; Figure 9.6). The alternation of these substrate types creates a mozaic of patches typically 1–5 km across, for example in the unit west of Thabazimbi.

Geology & Soils Vertic black ultramafic clays which developed from norite and gabbro, also locally in small depressions along streams. Some areas have less clay. Some with high base status and eutrophic red soils. Underlying geology is an Archaean granite-gneiss terrane of the Swazian Erathem that is covered in parts by the mainly clastic as well as chemical sediments and volcanics of the Rayton and Silverton Formation, both of the Pretoria Group (Transvaal Supergroup). Mafic intrusive rocks of the Rustenburg Layered Suite, Bushveld Igneous Complex (Late Vaalian) are present in the east and include the Bierkraal Manetite Gabbro. Bronzite, harzburgite, norite and anorthosite are the major mafic rocks of the Rustenburg Suite. Land types mainly Ea and Ae.

Climate Summer rainfall with very dry winters. MAP ranges from about 500–600 mm. This unit has the highest mean annual potential evaporation of savanna vegetation units outside the two Kalahari bioregions. Frost is fairly frequent in winter. See also climate diagram for SVcb 1 Dwaalboom Thornveld.

Important Taxa Tall Tree: *Acacia erioloba*. Small Trees: *Acacia erubescens* (d), *A. nilotica* (d), *A. tortilis* subsp. *heteracantha* (d), *A. fleckii*, *A. mellifera* subsp. *detinens*, *Combretum imberbe*, *Rhus lancea*, *Ziziphus mucronata*. Tall Shrubs: *Acacia hebeclada* subsp. *hebeclada*, *Combretum hereroense*, *Diospyros lycioides* subsp. *lycioides*, *Euclea undulata*, *Grewia flava*, *Tarchonanthus camphoratus*. Low Shrubs: *Acacia tenuispina* (d), *Abutilon austro-africanum*, *Aptosimum elongatum*, *Hirpicium bechuanense*, *Pavonia burchellii*, *Solanum delagoense*. Succulent Shrubs: *Kalanchoe rotundifolia*, *Talinum caffrum*. Herbaceous Climber: *Rhynchosia minima*. Graminoids: *Aristida bipartita* (d), *Bothriochloa insculpta* (d), *Digitaria eriantha* subsp. *eriantha* (d), *Ischaemum afrum* (d), *Panicum maximum* (d), *Cymbopogon pospischilii*, *Eragrostis curvula*, *Sehima galpinii*, *Setaria incrassata*. Herbs: *Heliotropium ciliatum*, *Kohautia caespitosa* subsp. *brachyloba*, *Nidorella hottentotica*.

Conservation Least threatened. Target 19%. Some 6% statutorily conserved, mostly within the Madikwe Game Reserve in the west. About 14% transformed mainly by cultivation. Erosion is very low to low. Main use is extensive cattle grazing.

Remarks Contains some very clayey soils that swell when wet and shrink when dry. On the clays, woody plant biomass is generally low and productivity of woody plants is usually lower than that of herbaceous plants. These areas with ultramafic soils are, contrary to Sekhukhuneland, low in species diversity and in endemic species.

References Coetzee (1971), Morris (1972), Van der Meulen (1979), Van der Meulen & Westfall (1980), Pauw (1988), Rutherford (1993), Winterbach (1998).

SVcb 2 Madikwe Dolomite Bushveld

VT 18 Mixed Bushveld (36%), VT 19 Sourish Mixed Bushveld (27%) (Acocks 1953). LR 18 Mixed Bushveld (78%) (Low & Rebelo 1996).

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Figure 9.10 SVcb 1 Dwaalboom Thornveld: *Acacia tortilis* trees and *Acacia tenuispina* low shrubs on medium clay soil, Steendal west-northwest of Dwaalboom, Limpopo Province.

Distribution North-West and Limpopo Provinces: Extends along the low ridge from the international border at Ramotswa in the west via the Rand Van Tweede Poort, Tlhapitse and Maakane to Modimong in the east. It is also found on dolomite hills between Assen and Northam. Altitude 1 000–1 300 m.

Vegetation & Landscape Features Gentle ridges and low hills up to about 100–150 m above the surrounding plains. Tree and shrub layers often not clearly distinct, especially on steeper slopes; they are dominated by deciduous trees, particularly *Combretum apiculatum* and *Kirkia wilmsii* (especially in the east). Herbaceous layer continuous, dominated by grasses.

Geology & Soils Stony, shallow soils of the Glenrosa and Mispah forms underlain mainly by dolomite, subordinate chert, minor carbonaceous shale, lime-

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Figure 9.11 SVcb 2 Madikwe Dolomite Bushveld: Tall *Combretum imberbe* and *Sclerocarya birrea* trees and smaller trees and shrubs of *C. apiculatum* on the Farm Abjaterskop with the vegetation type extending over the hill of Abjaterskop in the northern Marico District.

stone and quartzite of the Malmani Subgroup (Chuniespoort Group, Transvaal Supergroup, Vaalian Erathem). Land type is mainly Fa.

Climate Summer rainfall with very dry winters. MAP from about 520 mm in the west to 650 mm in the east. Frost fairly frequent in winter. See also climate diagram for SVcb 2 Madikwe Dolomite Bushveld.

Important Taxa Tall Tree: *Sclerocarya birrea* subsp. *caffra*. Small Trees: *Combretum apiculatum* (d), *Kirkia wilmsii* (d), *Ozoroa paniculosa* (d), *Rhus lancea* (d), *Combretum imberbe*, *Rhus leptodictya*, *Ximenia americana*, *Ziziphus mucronata*. Tall Shrubs: *Grewia flava* (d), *Tarchonanthus camphoratus* (d), *Vitex zeyheri* (d), *Clerodendrum glabrum*, *Grewia bicolor*, *G. monticola*. Graminoids: *Enneapogon scoparius* (d), *Heteropogon contortus* (d), *Aristida congesta*, *Panicum coloratum*, *P. maximum*.

Conservation Least threatened. Target 19%. Some 17% statutorily conserved in the Madikwe Nature Reserve. Only 1% transformed mostly by cultivation. Erosion is low to very low.

Remarks Some species distributions are associated with the east-west climatic gradient, for example *Kirkia wilmsii* is restricted to the eastern parts of the unit. In contrast to bush encroachment seen on the red clay loams surrounding this unit, the rocky soils of dolomitic origin support a more open canopy structure (Hudak & Wessman 2001).

References Zacharias (1994), Hudak & Wessman (2001).

SVcb 3 Zeerust Thornveld

VT 19 Sourish Mixed Bushveld (56%) (Acocks 1953). LR 18 Mixed Bushveld (55%) (Low & Rebelo 1996).

Distribution North-West Province: Extends along the plains from the Lobatsi River in the west via Zeerust, Groot Marico and Mabaalstad to the flats between the Pilanesberg and western end of the Magaliesberg in the east (including the valley of the lower Selons River). Altitude mainly 1 000–1 250 m.

Vegetation & Landscape Features Deciduous, open to dense short thorny woodland, dominated by *Acacia* species with herbaceous layer of mainly grasses on deep, high base-status and some clay soils on plains and lowlands, also between rocky ridges of SVcb 4 Dwarsberg-Swartruggens Mountain Bushveld.

Geology & Soils Sediments of the Pretoria Group (Transvaal Supergroup) in this area, particularly the Silverton and Rayton Formations, are mostly shale with less quartzite and conglomerate. Carbonates, volcanic rocks, breccias and diamictites also occur in the Pretoria Group. Bronzite, harzburgite, gabbro and norite of the Rustenburg Layered Suite (Bushveld Igneous Complex) are also found. Soils are mostly deep, red-yellow, apedal, freely drained with high base status also with some vertic or melanic clays. Land types mainly Ae and Ea.

Climate Summer rainfall with very dry winters. MAP has a relatively narrow range: 550–600 mm. Frost fairly frequent in winter. Mean monthly maximum and minimum temperatures for Marico-Irr weather station 36.7°C and –0.4°C for January and June, respectively. See also climate diagram for SVcb 3 Zeerust Thornveld.

Important Taxa Tall Trees: *Acacia burkei* (d), *A. erioloba* (d). Small Trees: *Acacia mellifera* subsp. *detinens* (d), *A. nilotica* (d), *A. tortilis* subsp. *heteracantha* (d), *Rhus lancea* (d), *Acacia fleckii*, *Peltophorum africanum*, *Terminalia sericea*. Tall Shrubs: *Diospyros lycioides* subsp. *lycioides*, *Grewia flava*, *Mystroxylon aethiopicum* subsp. *burkeanum*. Low Shrubs: *Agathisanthemum bojeri*, *Chaetacanthus costatus*, *Clerodendrum ternatum*, *Indigofera filipes*, *Rhus grandidens*, *Sida chrysantha*, *Stylosanthes fruticosa*. Graminoids: *Eragrostis lehmanniana* (d), *Panicum maximum* (d), *Aristida congesta*, *Cymbopogon pospischilii*. Herbs: *Blepharis*

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Figure 9.12 SVcb 3 Zeerust Thornveld: Moderately dense bushveld dominated by *Acacia tortilis* in the valley of the Doring River on Rykvoorby north of Zeerust, North-West Province.

integrifolia, *Chamaecrista absus*, *C. mimosoides*, *Cleome maculata*, *Dicoma anomala*, *Kyphocarpa angustifolia*, *Limeum viscosum*, *Lophiocarpus tenuissimus*.

Endemic Taxon Low Shrub: *Rhus maricoana*.

Conservation Least threatened. Target 19%. Less than 4% statutorily conserved, spread between four reserves including the Pienaar and Marico Bushveld Nature Reserves. Some 16% transformed mainly by cultivation, with some urban or built-up. A few areas with scattered plants of the alien *Cereus jamacaru* and several other alien species very scattered elsewhere. Erosion is mainly very low to low.

Remark This unit is somewhat more temperate than the SVcb 1 Dwaalboom Thornveld that borders it to the north.

References Van Wyk (1959), Van der Meulen (1979), Van der Meulen & Westfall (1980), Malan & Van Niekerk (2005).

SVcb 4 Dwarsberg-Swartruggens Mountain Bushveld

VT 19 Sourish Mixed Bushveld (80%) (Acocks 1953). LR 18 Mixed Bushveld (87%) (Low & Rebelo 1996).

Distribution North-West Province: Occurs on hills and ridges east of the Lobatsi River through the Zeerust and the Swartruggens areas to Mabeskraal and the Selons River Valley in the east. Also occurs on the parallel ridges of the Dwarsberge from Witkleigat in the west to the hills of the Dwarsberg area in the east. Altitude about 1 000–1 500 m.

Vegetation & Landscape Features Rocky low to medium high hills and ridges with some steep faces in places. Height above the surrounding plains can reach about 300 m. Variable vegetation structure depending on slope, exposure, aspect and local habitat—various combinations of tree and shrub layers often with dense grass layer. Bush clumps also occur.

Geology & Soils Shales, quartzites and andesites of the Pretoria Group (Transvaal Supergroup) with stony shallow soils of the Glenrosa and Mispah soil forms, with some deep, freely drained soils. Land types mainly Fb, Ib and Ae.

Climate Summer rainfall with very dry winters. MAP from about 550–650 mm. Frost fairly frequent in winter in lower-lying areas, less so on the hills. Mean monthly maximum and minimum temperatures for Lindleyspoort-Irr weather station 35.2°C and –0.4°C for January and June, respectively. See also climate diagram for SVcb 4 Dwarsberg-Swartruggens Mountain Bushveld.

Important Taxa Tall Tree: *Acacia robusta* (d). Small Trees: *Acacia caffra* (d), *A. erubescens* (d), *Burkea africana* (d), *Combretum apiculatum* (d), *Faurea saligna* (d), *Protea caffra* (d), *Combretum imberbe*, *C. molle*, *Cussonia paniculata*, *C. transvaalensis*, *Dombeya rotundifolia*, *Ozoroa paniculosa*, *Pappea capensis*, *Peltophorum africanum*, *Spirostachys africana*, *Vangueria infausta*, *Ziziphus mucronata*. Succulent Tree: *Aloe marlothii* subsp. *marlothii* (d). Tall Shrubs: *Dichrostachys cinerea* (d), *Croton pseudopulchellus*, *Ehretia rigida* subsp. *rigida*, *Grewia flava*, *Mundulea sericea*, *Tarchonanthus camphoratus*, *Vitex zeyheri*. Low Shrubs: *Athrixia elata*, *Pavonia burchellii*, *Rhus magalismontana* subsp. *magalismontana*, *R. rigida* var. *rigida*. Woody Climber: *Asparagus africanus*. Graminoids: *Aristida canescens* (d), *Cenchrus ciliaris* (d), *Chrysopogon serrulatus* (d), *Digitaria eriantha* subsp. *eriantha* (d), *Enneapogon scoparius* (d), *Loudetia simplex* (d), *Schizachyrium sanguineum* (d), *Setaria lindenbergiana* (d), *Bewsia biflora*, *Bothriochloa insculpta*, *Cymbopogon caesius*, *C. pospischilii*, *Elionurus muticus*, *Eragrostis rigidior*, *Fingerhuthia africana*, *Heteropogon contortus*, *Melinis nerviglumis*, *Panicum maximum*, *Setaria sphacelata*, *Themeda triandra*, *Trachypogon spicatus*, *Tristachya biseriata*. Herbs: *Barleria macrostegia*, *Commelina africana*, *Hermannia depressa*, *Senecio venosus*. Geophytic Herbs: *Hypoxis hemerocallidea*, *Pellaea calomelanos*, *Tritonia nelsonii*.

Biogeographically Important Taxon (Central Bushveld endemic) Tall Shrub: *Erythrophysa transvaalensis*.

Endemic Taxon Succulent Shrub: *Euphorbia perangusta*.

Conservation Least threatened. Target 24%. Less than 2% statutorily conserved, mainly in the Marico Bushveld Nature Reserve. Some 7% transformed, mainly by cultivation. Aliens include scattered *Cereus jamacaru* and *Acacia mearnsii* in few areas. Erosion is mainly very low to low.

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Figure 9.13 SVcb 4 Dwarsberg-Swartruggens Mountain Bushveld: Northwestern slopes with *Vangueria infausta*, *Dombeya rotundifolia*, *Acacia caffra* and *Rhus* species in the foreground, on Sephton's Nek, north of Zeerust.

Remarks This vegetation has some similarities with the SVcb 9 Gold Reef Mountain Bushveld to the east but is drier and warmer than this unit. The unit extends into Botswana, for example on the hills around Lobatse.

References Van der Meulen (1979), Zacharias (1994), Bredenkamp (1999).

SVcb 5 Pilanesberg Mountain Bushveld

VT 20 Sour Bushveld (83%) (Acocks 1953). LR 18 Mixed Bushveld (100%) (Low & Rebelo 1996).

Distribution North-West Province: Hills and mountains immediately north of Sun City and west of Heystekrand (Mankwe District). Altitude about 1 100–1 500 m.

Vegetation & Landscape Features A near circular (diameter 23–27 km) complex constituting an intrusive and extrusive massif with the original volcanic caldera almost eroded away leaving a broken ring of hills and low mountains as

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Figure 9.14 SVcb 5 Pilanesberg Mountain Bushveld: Bushveld with *Combretum molle* on south-facing slopes above Mankwe Dam in the centre of the Pilanesberg Game Reserve.

well as the eroded intrusions of the core remaining in the form of many hills and low mountains. Valley floors between the hills and mountains tend to be at most 1–2 km wide. Broad-leaved deciduous bushveld with trees and shrubs with grass layer on slopes of mountains and hills, with mountain summits more grassy and valley floors sometimes less woody but the latter may be related to past disturbance (see section on Conservation below).

Geology & Soils The alkaline complex consists of potassium- and sodium-rich, silica-poor rocks, mainly foyaite, lava and tuff with some syenite. Wide range of elements found, particularly rare earth elements and fluorine in the form of CaF_2 (flourite). Due to the original volcanic actions, subsequent fracturing, emplacement of intrusions, collapse and resurgence of magma and radial emplacement of dykes, a complex geological pattern exists. Pilanesberg is one of the very few large alkaline ring complexes in the world, approximately 1.3 gya old. Soils are shallow, rocky lithosols on the hills and mountains of the Glenrosa and Mispah soil forms, but with deeper soils on the valley floors. Land type is mostly Ib.

Climate Summer rainfall with very dry winters. MAP from about 600–700 mm. Frost fairly frequent in winter in lower-lying areas, less so on the hills. Mean monthly maximum and minimum temperatures for Manyane Gate (eastern entrance to Pilanesberg Game Reserve) 36.7°C and –2.2°C for February and July, respectively. See also climate diagram for SVcb 5 Pilanesberg Mountain Bushveld.

Important Taxa Small Trees: *Combretum apiculatum* (d), *C. molle* (d), *C. zeyheri* (d), *Strychnos cocculoides* (d), *Croton gratissimus*, *Englerophytum magalismontanum*, *Rhus leptodictya*, *Vangueria parvifolia*. Tall Shrubs: *Diplorhynchus condylocarpon* (d), *Elephantorrhiza burkei* (d), *Grewia flava*, *Hibiscus calyphyllus*, *Mundulea sericea*, *Steganotaenia araliacea*, *Vitex rehmannii*. Low Shrub: *Polygala hottentotta*. Graminoids: *Chrysopogon serrulatus* (d), *Elionurus muticus* (d), *Panicum maximum* (d), *Themeda triandra* (d), *Enneapogon scoparius*, *Hyperthelia dissoluta*, *Panicum deustum*. Herbs: *Abutilon pycnodon*, *Chamaesyce inaequilatera*, *Hermannia depressa*, *Nidorella resedifolia*, *Xerophyta retinervis*. Succulent Herb: *Crassula lanceolata* subsp. *transvaalensis*.

Biogeographically Important Taxon (Central Bushveld endemic) Tall Shrub: *Erythrophysa transvaalensis*.

Conservation Least threatened. Target of 24% exceeded, with 96% statutorily conserved in the Pilanesberg Game Reserve. Almost 2% transformed, mainly by urban development on the periphery. Prior to the proclamation of the reserve in 1979 some of the area had been intensively farmed and included some bush-clearing. Some of these areas are still visible, for example high grass cover and low tree cover in the lowlands. A few old mining sites occur. There are some scattered alien plant populations of *Cereus jamacaru*. Erosion is very low.

Remarks This unit is a meeting ground for several species of *Grewia*, for example northwestern limits of *G. occidentalis*, southwestern limits of *G. monticola* and *G. hexamita* and southeastern limits of *G. retinervis*. The vegetation of the southern slopes of this unit is similar to that of the southern slopes of the northeastern end of the Magaliesberg (SVcb 9 Gold Reef Mountain Bushveld) whereas the northern slopes of the two units have distinct physiognomic differences (Van Wyk 1959).

Reference Van Wyk (1959).

SVcb 6 Marikana Thornveld

VT 19 Sourish Mixed Bushveld (46%), VT 13 Other Turf Thornveld (34%) (Acocks 1953). LR 14 Clay Thorn Bushveld (60%) (Low & Rebelo 1996).

Distribution North-West and Gauteng Provinces: Occurs on plains from the Rustenburg area in the west, through Marikana and Brits to the Pretoria area in the east. Altitude about 1 050–1 450 m.

Vegetation & Landscape Features Open *Acacia karroo* woodland, occurring in valleys and slightly undulating plains, and some lowland hills. Shrubs are more dense along drainage lines, on termitaria and rocky outcrops or in other habitat protected from fire.

Geology & Soils Most of the area is underlain by the mafic intrusive rocks of the Rustenburg Layered Suite of the Bushveld Igneous Complex. Rocks include gabbro, norite, pyroxenite and anorthosite. The shales and quartzites of the Pretoria Group (Transvaal Supergroup) also contribute. Mainly vertic melanic clays with some dystrophic or mesotrophic plinthic catenas and some freely drained, deep soils. Land types mainly Ea, Ba and Ae.

Climate Summer rainfall with very dry winters. MAP between about 600 and 700 mm. Frost fairly frequent in winter. Mean monthly maximum and minimum temperatures for Brits-Agr 35.3°C and –3.3°C for January and June, respectively. Corresponding values are 35.3°C and –1.4°C for Rustenberg (November and July) and 32.8°C and –1.0°C for Pretoria University Experimental Farm (January and July). This unit has a relatively more temperate climate than the SVcb 1 Dwaalboom Thornveld. See also climate diagram for SVcb 6 Marikana Thornveld.

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Figure 9.15 SVcb 6 Marikana Thornveld: *Acacia nilotica*-dominated clay thornveld north of Pretoria (near Ga-Rankuwa, Gauteng) after recent fire.

SVcb 7 Norite Koppies Bushveld

VT 19 Sourish Mixed Bushveld (82%) (Acocks 1953). LR 14 Clay Thorn Bushveld (87%) (Low & Rebelo 1996). *Croton gratissimus–Setaria lindenbergiana* Woodland (Van der Meulen 1979).

Distribution North-West and Gauteng Provinces: Embedded in Marikana Thornveld, north of the Magaliesberg, on rocky hills between Rustenburg and Pretoria with the highest hills (e.g. Kareepoortberg) near Brits. Altitude about 1 100–1 350 m.

Vegetation & Landscape Features A low, semi-open to closed woodland up to 5 m tall, consisting of dense deciduous shrubs and trees with very sparse undergrowth on shallow soils, with large areas not covered by vegetation. Tree and shrub layers are continuous. The stands of this unit are found on noritic outcrops and koppies, many appearing as inselbergs above the surrounding plains.

Geology & Soils Mostly gabbro and norite with interlayered anorthosite of the Pyramid Gabbro-Norite, Rustenburg Layered Suite, with a small area of the Rashoop Granophyre Suite (felsic igneous rocks), both of the Bushveld Complex (Vaalian). Large rock boulders and very shallow lithosols occur. Soils are well-drained, Glenrosa and Mispah forms; in some areas vertic, melanic clays are found as well. Land types mainly Ib, with some Ea also occurring.

Climate Summer rainfall with dry winters. MAP from 600–700 mm. Frost fairly frequent around the base of hills in winter but less so on the hills. See also climate diagram for SVcb 7 Norite Koppies Bushveld.

Important Taxa Tall Tree: *Sclerocarya birrea* subsp. *caffra*. Small Trees: *Combretum molle* (d), *Croton gratissimus* (d), *Ficus abutilifolia* (d), *Pappea capensis* (d), *Acacia caffra*, *Bridelia mollis*, *Combretum apiculatum*, *Cussonia paniculata*,

Important Taxa Tall Tree: *Acacia burkei*. Small Trees: *Acacia caffra* (d), *A. gerrardii* (d), *A. karroo* (d), *Combretum molle* (d), *Rhus lancea* (d), *Ziziphus mucronata* (d), *Acacia nilotica, A. tortilis* subsp. *heteracantha*, *Celtis africana*, *Dombeya rotundifolia*, *Pappea capensis*, *Peltophorum africanum*, *Terminalia sericea*. Tall Shrubs: *Euclea crispa* subsp. *crispa* (d), *Olea europaea* subsp. *africana* (d), *Rhus pyroides* var. *pyroides* (d), *Diospyros lycioides* subsp. *guerkei*, *Ehretia rigida* subsp. *rigida*, *Euclea undulata*, *Grewia flava*, *Pavetta gardeniifolia*. Low Shrubs: *Asparagus cooperi* (d), *Rhynchosia nitens* (d), *Indigofera zeyheri*, *Justicia flava*. Woody Climbers: *Clematis brachiata* (d), *Helinus integrifolius*. Herbaceous Climbers: *Pentarrhinum insipidum* (d), *Cyphostemma cirrhosum*. Graminoids: *Elionurus muticus* (d), *Eragrostis lehmanniana* (d), *Setaria sphacelata* (d), *Themeda triandra* (d), *Aristida scabrivalvis* subsp. *scabrivalvis*, *Fingerhuthia africana*, *Heteropogon contortus*, *Hyperthelia dissoluta*, *Melinis nerviglumis*, *Pogonarthria squarrosa*. Herbs: *Hermannia depressa* (d), *Ipomoea obscura* (d), *Barleria macrostegia*, *Dianthus mooiensis* subsp. *mooiensis*, *Ipomoea oblongata*, *Vernonia oligocephala*. Geophytic Herbs: *Ledebouria revoluta*, *Ornithogalum tenuifolium*, *Sansevieria aethiopica*.

Conservation Endangered. Target 19%. Less than 1% statutorily conserved in, for example, Magaliesberg Nature Area. More conserved in addition in other reserves, mainly in De Onderstepoort Nature Reserve. Considerably impacted, with 48% transformed, mainly cultivated and urban or built-up areas. Most agricultural development of this unit is in the western regions towards Rustenburg, while in the east (near Pretoria) industrial development is a greater threat of land transformation. Erosion is very low to moderate. Alien invasive plants occur localised in high densities, especially along the drainage lines.

Remark A few small ridges of SVcb 9 Gold Reef Mountain Bushveld in the Pretoria area have not been mapped separately from this unit.

References Van der Meulen (1979), Van Rooyen (1983, 1984), Panagos et al. (1998).

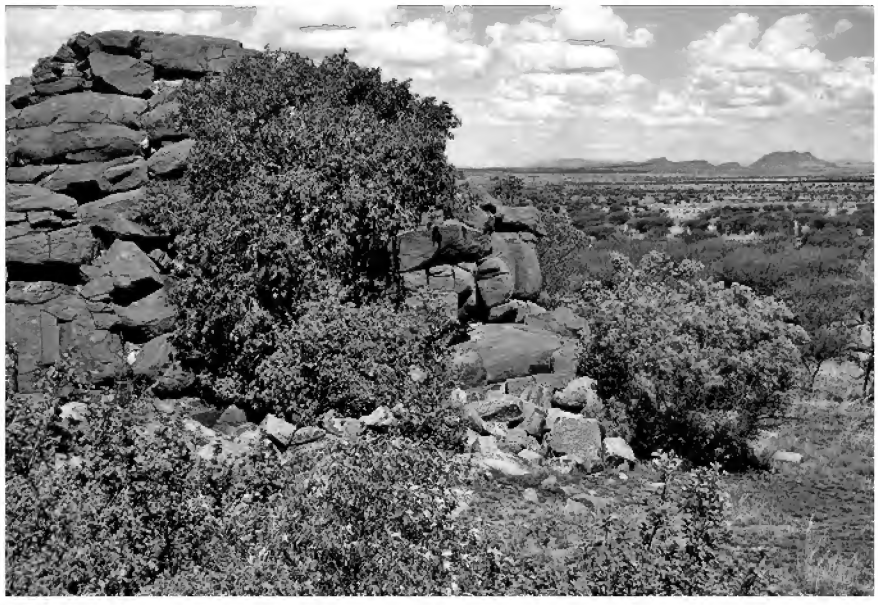

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Figure 9.16 SVcb 7 Norite Koppies Bushveld: Small norite koppie overlooking plains covered with Marikana Thornveld northeast of Rustenburg, North-West Province.

Dombeya rotundifolia, *Faurea saligna*, *Ficus glumosa*, *Lannea discolor*, *Obetia tenax*, *Peltophorum africanum*, *Rhus leptodictya*, *Vangueria infausta*, *Ziziphus mucronata*. Succulent Tree: *Euphorbia cooperi*. Tall Shrubs: *Triaspis glaucophylla* (d), *Canthium gilfillanii*, *Clerodendrum glabrum*, *Diplorhynchus condylocarpon*, *Euclea natalensis*, *Grewia flavescens*, *G. monticola*, *Gymnosporia nemorosa*, *G. polyacantha*, *Pavetta eylesii*, *Pouzolzia mixta*, *Psydrax livida*, *Vitex zeyheri*. Low Shrubs: *Jatropha latifolia* var. *latifolia* (d), *Abutilon austro-africanum*, *Hermannia floribunda*, *Hibiscus subreniformis*, *Rhus zeyheri*. Succulent Shrub: *Tetradenia brevispicata*. Semiparasitic Shrub: *Osyris lanceolata*. Woody Climbers: *Helinus integrifolius*, *Rhoicissus tridentata*, *Turraea obtusifolia*. Woody Succulent Climber: *Sarcostemma viminale*. Herbaceous Climber: *Cyphostemma lanigerum*. Graminoids: *Chrysopogon serrulatus* (d), *Setaria lindenbergiana* (d), *Aristida congesta*, *Bulbostylis humilis*, *Eustachys paspaloides*, *Heteropogon contortus*, *Loudetia simplex*, *Melinis nerviglumis*, *Panicum maximum*, *Themeda triandra*. Herb: *Hibiscus sidiformis*. Geophytic Herbs: *Pellaea calomelanos*, *P. viridis*, *Scadoxus puniceus*.

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Figure 9.17 SVcb 8 Moot Plains Bushveld: *Rhus lancea* and *Acacia nilotica* dominant on flats at an altitude of 1 325 m at Hekpoort, west of Pretoria.

Conservation Least threatened according to remote sensing data, but ground truthing suggests that it is rather susceptable. Target 24%. None conserved in statutory reserves but 4% conserved in De Onderstepoort Nature Reserve. About 10% transformed (but more recent assessment suggests about 20%), especially at the unit fringes, mainly by mining as well as urban and built-up developments and cultivated areas. Mining is primarily in the form of granite quarries on koppies, but also affects surrounding lower-lying areas. Areas close to human settlements are often severely disturbed and many woody species may have been harvested from these areas for fuel or building materials. Weeds, including a number of declared aliens, are more common in these disturbed sites. Erosion is very low to moderate.

Remarks Vegetation patterns on norite koppies are primarily determined by the amount of rockiness and aspect, warmer north-facing slopes and cooler south-facing slopes bearing floristically distinct vegetation. A number of the woody species, e.g. species of *Ficus*, are typical chasmophytes, penetrating the rocks with their roots (Van der Meulen 1979). The vegetation unit is transitional between xeric lowland bushveld and mesophyllous woodland in cooler more moist upland areas associated with the Magaliesberg and may be considered to be a more xeric phase of these upland areas (Van der Meulen 1979).

References Van der Meulen (1979), Panagos (1996).

SVcb 8 Moot Plains Bushveld

VT 19 Sourish Mixed Bushveld (57%) (Acocks 1953). LR 18 Mixed Bushveld (83%) (Low & Rebelo 1996).

Distribution North-West and Gauteng Provinces: Main belt occurs immediately south of the Magaliesberg from the Selons River Valley in the west through Maanhaarrand, filling the valley bottom of the Magalies River, proceeding east of the Hartebeestpoort Dam between the Magaliesberg and Daspoort mountain ranges to Pretoria. It also occurs as a narrow belt immediately north of the Magaliesberg from Rustenburg in the west to just east of the Crocodile River in the east: also south of the Swartruggens–Zeerust line. Altitude typically about 1 050–1 450 m.

Vegetation & Landscape Features Open to closed, low, often thorny savanna dominated by various species of *Acacia* in the bottomlands and plains as well as woodlands of varying height and density on the lower hillsides. Herbaceous layer is dominated by grasses.

Geology & Soils Clastic sediments and minor carbonates and volcanics of the Pretoria Group (including the Silverton Formation) and some Malmani dolomites in the west, all of the Transvaal Supergroup (Vaalian). There is also some contribution from mafic Bushveld intrusives. Soils often stony with colluvial clay-loam but varied, including red-yellow apedal freely drained, dystrophic and eutrophic plinthic catenas, vertic and melanic clays, and some less typical Glenrosa and Mispah forms. Land types Ae, Ba, Ea, Bc, Ac and less typically Fb.

Climate Summer rainfall with very dry winters. MAP from about 55 mm in the west to about 700 mm in the east. Frost frequent in winter. Mean monthly maximum and minimum temperatures for Pretoria-Pur 33.6°C and –3.1°C for January and June, respectively. See also climate diagram for SVcb 8 Moot Plains Bushveld.

Important Taxa Small Trees: *Acacia nilotica* (d), *A. tortilis* subsp. *heteracantha* (d), *Rhus lancea* (d). Tall Shrubs: *Buddleja saligna* (d), *Euclea undulata* (d), *Olea europaea* subsp. *africana* (d), *Grewia occidentalis*, *Gymnosporia polyacantha*, *Mystroxylon aethiopicum* subsp. *burkeanum*. Low Shrubs: *Aptosimum elongatum*, *Felicia fascicularis*, *Lantana rugosa*, *Teucrium trifidum*. Succulent Shrub: *Kalanchoe paniculata*. Woody Climber: *Jasminum breviflorum*. Herbaceous Climber: *Lotononis bainesii*. Graminoids: *Heteropogon contortus* (d), *Setaria sphacelata* (d), *Themeda triandra* (d), *Aristida congesta*, *Chloris virgata*, *Cynodon dactylon*, *Sporobolus nitens*, *Tragus racemosus*. Herbs: *Achyropsis avicularis*, *Corchorus asplenifolius*, *Evolvulus alsinoides*, *Helichrysum nudifolium*, *H. undulatum*, *Hermannia depressa*, *Osteospermum muricatum*, *Phyllanthus maderaspatensis*.

Conservation Vulnerable. Target 19%. Some 13% statutorily conserved mainly in the Magaliesberg Nature Area. About 28% transformed mainly by cultivation and urban and built-up areas. Very scattered occurrences to sometimes dense patches in places of various alien plants including *Cereus jamacaru*, *Eucalyptus* species, *Jacaranda mimosifolia*, *Lantana camara*, *Melia azedarach* and *Schinus* species. Erosion is mainly very low to low, moderate in some areas.

References Coetzee (1975), Van der Meulen (1979).

SVcb 9 Gold Reef Mountain Bushveld

VT 61 Bankenveld (50%) (Acocks 1953). LR 18 Mixed Bushveld (44%), LR 34 Rocky Highveld Grassland (43%) (Low & Rebelo 1996).

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Figure 9.18 SVcb 9 Gold Reef Mountain Bushveld: *Protea caffra* and the dominant *Acacia caffra* on the southern slopes of the Magaliesberg at an altitude of 1 655 m in the Magaliesberg Conservation Area, north of Boschfontein and southeast of Rustenburg.

Distribution North-West, Gauteng, Free State and Mpumalanga Provinces: Occurs along rocky quartzite ridges of the Magaliesberg and the parallel ridge to the south, from around Boshoek and Koster in the west to near Bronkhorstspruit in the east. The west-east-trending ridge of the Witwatersrand from around Krugersdorp in the west, through Roodepoort and Johannesburg to Bedfordview (Germiston District). Inner ridges (e.g. Dwarsberg and Witkop) of the Vredefort Dome on the Vaal River northwest of Parys and part of the Suikerbosrand and some other hills around Heidelberg. Altitude 1 200–1 750 m.

Vegetation & Landscape Features Rocky hills and ridges often west-east trending with more dense woody vegetation often on the south-facing slopes associated with distinct floristic differences (e.g. preponderance of *Acacia caffra* on the southern slopes). Tree cover elsewhere is variable. Tree and shrub layers are often continuous. Herbaceous layer is dominated by grasses.

Geology & Soils This area consists predominantly of quartzites, conglomerates and some shale horizons of the Magaliesberg, Daspoort and Silverton Formations (Vaalian Pretoria Group) and the Hospital Hill, Turffontein and Government Subgroups (Randian Witwatersrand Supergroup). Soils are shallow, gravel lithosols of the Mispah and Glenrosa forms. Land types mainly Ib and Fb.

Climate Summer rainfall with very dry winters. MAP about 600–750 mm. Frost frequent in winter (especially in the south), but less common on the ridges and hills. Mean monthly maximum and minimum temperatures for Krugersdorp 30.8°C and –1.8°C for January and July, respectively. See also climate diagram for SVcb 9 Gold Reef Mountain Bushveld.

Important Taxa Small Trees: *Acacia caffra* (d), *Combretum molle* (d), *Protea caffra* (d), *Celtis africana*, *Dombeya rotundifolia*, *Englerophytum magalismontanum*, *Ochna pretoriensis*, *Rhus leptodictya*, *Vangueria infausta*, *V. parvifolia*, *Ziziphus mucronata*. Tall Shrubs: *Canthium gilfillanii*, *Ehretia rigida* subsp. *rigida*, *Grewia occidentalis*, *Gymnosporia buxifolia*, *Mystroxylon aethiopicum* subsp. *burkeanum*. Low Shrubs: *Athrixia elata*, *Pearsonia cajanifolia*, *Rhus magalismontana* subsp. *magalismontana*, *R. rigida* var. *rigida*. Woody Climber: *Ancylobotrys capensis*. Graminoids: *Loudetia simplex* (d), *Panicum natalense* (d), *Schizachyrium sanguineum* (d), *Trachypogon spicatus* (d), *Alloteropsis semialata* subsp. *eckloniana*, *Bewsia biflora*, *Digitaria tricholaenoides*, *Diheteropogon amplectens*, *Sporobolus pectinatus*, *Tristachya biseriata*, *T. leucothrix*. Herbs: *Helichrysum nudifolium*, *H. rugulosum*, *Pentanisia angustifolia*, *Senecio venosus*, *Xerophyta retinervis*. Geophytic Herbs: *Cheilanthes hirta*, *Hypoxis hemerocallidea*, *Pellaea calomelanos*.

Endemic Taxa Succulent Shrub: *Aloe peglerae*. Succulent Herb: *Frithia pulchra*.

Conservation Least threatened. Target 24%. Some 22% statutorily conserved mainly in the Magaliesberg Nature Area and much smaller proportions in the Rustenberg, Wonderboom and Suikerbosrand Nature Reserves. At least an additional 1% conserved in other reserves brings the total conserved very close to target. About 15% transformed mainly by cultivation and urban and built-up areas. Some areas with dense stands of the alien *Melia azedarach* but which is often associated with drainage lines or alluvia (i.e. azonal vegetation) embedded within this unit. Erosion is very low to low.

Remark A few small ridges of this unit in the Pretoria area have not been mapped.

References Van Vuuren & Van der Schijff (1970), Bredenkamp (1975), Coetzee (1975), Bredenkamp (1977), Bredenkamp & Theron (1978), Behr & Bredenkamp (1988), Bezuidenhout et al. (1988), Du Preez & Venter (1990), Coetzee et al. (1993), Bezuidenhout et al. (1994), Coetzee et al. (1994, 1995), Grobler et al. (2002).

SVcb 10 Gauteng Shale Mountain Bushveld

VT 61 Bankenveld (98%) (Acocks 1953). LR 34 Rocky Highveld Grassland (85%) (Low & Rebelo 1996).

Distribution Gauteng and North-West Provinces: Occurs mainly on the ridge of the Gatsrand south of Carletonville–Westonaria–Lenasia. Also occurs as a narrow band along the ridge that runs from a point between Tarlton and Magaliesberg in the west, through Sterkfontein, Pelindaba, Atteridgeville to Klapperkop and southeastern Pretoria in the east. Altitude 1 300–1 750 m.

Vegetation & Landscape Features Low, broken ridges varying in steepness and with high surface rock cover. Vegetation is a short (3–6 m tall), semi-open thicket dominated by a variety of woody species including *Acacia caffra*, *Rhus leptodictya*, *R. magalismontana*, *Cussonia spicata*, *Ehretia rigida*, *Maytenus heterophylla*, *Euclea crispa*, *Zanthoxylum capense*, *Dombeya rotundifolia*, *Protea caffra*, *Celtis africana*, *Ziziphus mucronata*, *Vangueria infausta*, *Canthium gilfillanii*, *Englerophytum magalismontanum*, *Combretum molle*, *Ancylobotrys capensis*, *Olea europaea* subsp. *africana* and *Grewia occidentalis*. The understorey is dominated by a variety of grasses. Some of the ridges form plateaus above the northern slopes that carry scrubby grassland with high surface rock cover.

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Figure 9.19 SVcb 10 Gauteng Shale Mountain Bushveld: Typical semi-open bushveld on rocky slope with a variety of woody species, including *Cussonia spicata*, *Euclea crispa* and *Dombeya rotundifolia* in Groenkloof Nature Reserve, Pretoria. The tall grass in the foreground is *Hyparrhenia dregeana*.

Geology & Soils Dominated by shale and some coarser clastic sediments as well as significant andesite from the Pretoria Group (Transvaal Supergroup), all sedimentary rocks. A part of the area is underlain by Malmani dolomites of the Chuniespoort Group (Transvaal Supergroup). Soils are mostly shallow Mispah, but are deeper at the foot of the slopes. Land type is mostly Fb, with some Ib.

Climate Summer rainfall with very dry winters. MAP 600–750 mm, increasing from west to east as well as with higher elevation. Frost frequent, higher in the west and south. See also climate diagram for SVcb 10 Gauteng Shale Mountain Bushveld.

Important Taxa Small Trees: *Acacia caffra* (d), *Dombeya rotundifolia* (d), *Acacia karroo*, *Celtis africana*, *Combretum molle*, *Cussonia spicata*, *Englerophytum magalismontanum*, *Protea caffra*, *Rhus leptodictya*, *Vangueria infausta*, *Zanthoxylum capense*, *Ziziphus mucronata*. Tall Shrubs: *Asparagus laricinus*, *Canthium gilfillanii*, *Chrysanthemoides monilifera*, *Dichrostachys cinerea*, *Diospyros austro-africana*, *D. lycioides* subsp. *lycioides*, *Ehretia rigida* subsp. *rigida*, *Euclea crispa* subsp. *crispa*, *Grewia occidentalis*, *Gymnosporia polyacantha*, *Olea europaea* subsp. *africana*, *Tephrosia capensis*, *T. longipes*. Low Shrubs: *Acalypha angustata*, *Asparagus suaveolens*, *Athrixia elata*, *Felicia muricata*, *Indigofera comosa*, *Rhus magalismontana* subsp. *magalismontana*. Geoxylic Suffrutex: *Elephantorrhiza elephantina*. Succulent Shrub: *Kalanchoe rotundifolia*. Woody Climber: *Ancylobotrys capensis*. Graminoids: *Hyparrhenia dregeana* (d), *Cymbopogon caesius*, *C. pospischilii*, *Digitaria eriantha* subsp. *eriantha*, *Eragrostis curvula*. Herbs: *Dicoma zeyheri*, *Helichrysum nudifolium*, *H. rugulosum*, *Hermannia lancifolia*, *Hibiscus pusillus*, *Selaginella dregei*, *Senecio venosus*, *Vernonia natalensis*, *V. oligocephala*. Geophytic Herbs: *Cheilanthes hirta*, *Pellaea calomelanos*, *Scadoxus puniceus*.

Conservation Vulnerable. Target 24%. Less than 1% statutorily conserved in, for example, the Skanskop and Hartbeesthoek Nature Reserves, Magaliesberg Nature Area and Groenkloof National Park. Additionally, over 1% conserved in other reserves including the John Nash Nature Reserve, Cheetah Park and Hartbeesthoek Radio Astronomy Observatory. About 21% transformed mainly by urban and built-up areas, mines and quarries, cultivation and plantations. Wattles a common invasive plant in places. Erosion very low to low.

Remarks This unit represents the arid western part of the ridges of Rocky Highveld Grassland (Low & Rebelo 1996) or Bankenveld (Acocks 1988). In species composition and vegetation structure it is similar to and positioned adjacent to SVcb 11 Andesite Mountain Bushveld. This unit occurs more frequently on warmer north-facing slopes and is underlain by rocks of sedimentary origin, whereas SVcb 11 Andesite Mountain Bushveld occurs more frequently on cooler south-facing slopes and is underlain by rocks of volcanic origin.

References Coetzee (1972, 1974), Bezuidenhout et al. (1994).

SVcb 11 Andesite Mountain Bushveld

VT 61 Bankenveld (62%) (Acocks 1953). LR 39 Moist Cool Highveld Grassland (45%), LR 34 Rocky Highveld Grassland (37%) (Low & Rebelo 1996).

Distribution Gauteng, North-West, Mpumalanga and Free State Provinces: Several separate occurrences of which the main are: the Bronberg Ridge in eastern Pretoria extending to Welbekend; from Hartebeesthoek in the west along the valley between the two parallel ranges of hills to Atteridgeville; hills in southern Johannesburg; several hills encompassing Nigel, Willemsdal, Coalbrook and Suikerbosrand (in part); and the outer ring of ridges of the Vredefort Dome and some hills to the northwest around Potchefstroom. Altitude about 1 350–1 800 m.

Vegetation & Landscape Features Dense, medium-tall thorny bushveld with a well-developed grass layer on hill slopes and some valleys with undulating landscape.

Geology & Soils Tholeitic basalt of the Klipriviervberg Group (Randian Ventersdorp Supergroup), also dark shale, micaceous sandstone and siltstone and thin coal seams of the Madzaringwe Formation [Karoo Supergroup, and andesite and conglomerate of the Pretoria Group (Vaalian Transvaal Supergroup)]. Weathering of these rocks gives rise to shallow,

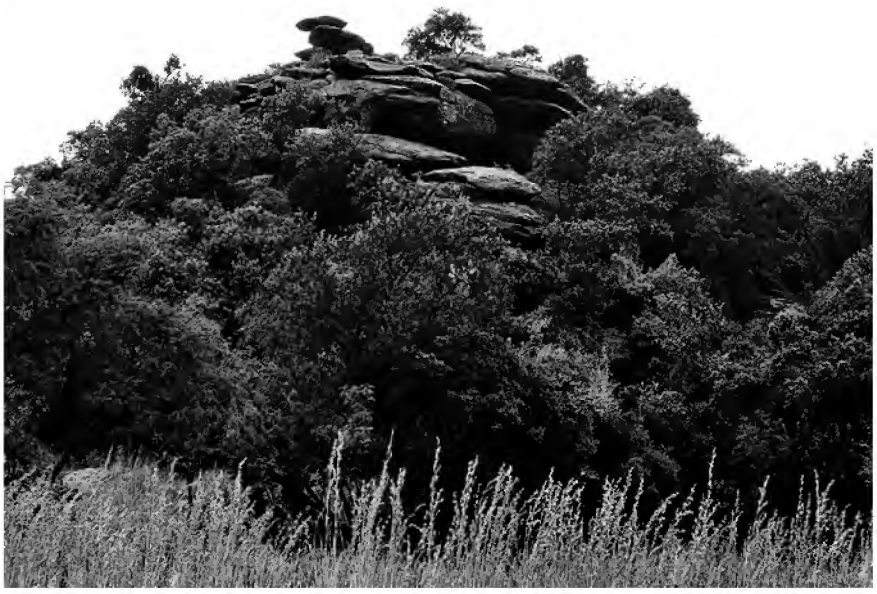

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Figure 9.20 SVcb 11 Andesite Mountain Bushveld: *Acacia caffra* and *Euclea crispa* on a rocky koppie at an altitude of 1 385 m on Hartebeeshoek north of Krugersdorp.

rocky, clayey soils of mainly Mispah and Glenrosa soil forms. Land types mainly Ib and Fb, with some Ba and Bb.

Climate Summer rainfall with very dry winters. MAP from about 550 mm in the southwest to about 750 mm in the northeast. Frequent frost in winter, but less on the ridges and hills. See also climate diagram for SVcb 11 Andesite Mountain Bushveld.

Important Taxa Small Trees: *Acacia caffra* (d), *A. karroo* (d), *Celtis africana*, *Protea caffra*, *Zanthoxylum capense*, *Ziziphus mucronata*. Tall Shrubs: *Asparagus laricinus* (d), *Euclea crispa* subsp. *crispa* (d), *Rhus pyroides* var. *pyroides* (d), *Diospyros lycioides* subsp. *lycioides*, *Gymnosporia polyacantha*, *Lippia javanica*, *Rhamnus prinoides*. Low Shrubs: *Asparagus suaveolens* (d), *Rhus rigida* var. *margaretae*, *Teucrium trifidum*. Soft Shrub: *Isoglossa grantii*. Woody Climber: *Rhoicissus tridentata*. Graminoids: *Eragrostis curvula* (d), *Hyparrhenia hirta* (d), *Setaria sphacelata* (d), *Themeda triandra* (d), *Cymbopogon pospischilii*, *Digitaria eriantha* subsp. *eriantha*, *Elionurus muticus*, *Eragrostis racemosa*, *E. superba*, *Panicum maximum*. Herbs: *Commelina africana*, *Vernonia galpinii*, *V. oligocephala*. Succulent Herb: *Aloe greatheadii* var. *davyana*.

Conservation Least threatened. Target 24%. About 7% statutorily conserved mainly in the Suikerbosrand Nature Reserve and Magaliesberg Nature Area. An additional 1–2% conserved in other reserves mainly in the Hartbeesthoek Radio Astronomy Observatory. Some 15% already transformed, mainly cultivated and some urban and built-up areas. Some of the unit fringes on major urban areas. Erosion is generally very low.

References Bredenkamp (1975, 1977), Bredenkamp & Theron (1980), Du Preez & Venter (1990), Coetzee et al. (1995), Grobler (2000).

SVcb 12 Central Sandy Bushveld

VT 18 Mixed Bushveld (44%), VT 19 Sourish Mixed Bushveld (32%) (Acocks 1953). LR 18 Mixed Bushveld (73%) (Low & Rebelo 1996).

Distribution Limpopo, Mpumalanga, Gauteng and North-West Provinces: Undulating terrain occurs mainly in a broad arc south of the Springbokvlakte from the Pilanesberg in the west through Hammanskraal and Groblersdal to GaMasemola in the east. A generally narrow irregular band along the northwestern edge of the Springbokvlakte (including Modimolle) extending into a series of valleys and lower-altitude areas within the Waterberg including the upper Mokolo River Valley near Vaalwater, the corridor between Rankins Pass and the Doorndraai Dam, and the lowlands from the Mabula area to south of the Hoekberge. Some isolated sandy rises are found on the Springbokvlakte. Altitude about 850–1 450 m.

Vegetation & Landscape Features Low undulating areas, sometimes between mountains, and sandy plains and catenas supporting tall, deciduous *Terminalia sericea* and *Burkea africana* woodland on deep sandy soils (with the former often dominant on the lower slopes of sandy catenas) and low, broad-leaved *Combretum* woodland on shallow rocky or gravelly soils. Species of *Acacia*, *Ziziphus* and *Euclea* are found on flats and lower slopes on eutrophic sands and some less sandy soils. *A. tortilis* may dominate some areas along valleys. Grass-dominated herbaceous layer with relatively low basal cover on dystrophic sands.

Geology & Soils The large southern and eastern parts of this area are underlain by granite of the Lebowa Granite Suite and some granophyre of the Rashoop Granophyre Suite (both Bushveld Complex, Vaalian). In the north, the sedimentary rocks of the Waterberg Group (Mokolian Erathem) are most important. Specifically, sandstone, conglomerate and siltstone of the Alma Formation and sandstone, siltstone and shale of the Vaalwater Formation. Well-drained, deep Hutton or Clovelly soils often with a catenary sequence from Hutton at the top to Clovelly on the lower slopes; shallow, skeletal Glenrosa soils also occur. Land types mainly Bb, Fa, Ba, Bd and Ac.

Climate Summer rainfall with very dry winters. Effectively three seasons, namely a cool dry season from May to mid-August, a hot dry season from mid-August to about October and a hot wet season from about November to April. MAP from about 500–700 mm. Frost fairly infrequent. Mean monthly maximum and minimum temperatures for Goedehoop (in the northern part of this vegetation unit) 35.3°C and –3.1°C for November and June, respectively. See also climate diagram for SVcb 12 Central Sandy Bushveld.

Important Taxa Tall Trees: *Acacia burkei* (d), *A. robusta*, *Sclerocarya birrea* subsp. *caffra*. Small Trees: *Burkea africana* (d), *Combretum apiculatum* (d), *C. zeyheri* (d), *Terminalia sericea* (d), *Ochna pulchra*, *Peltophorum africanum*, *Rhus leptodictya*. Tall Shrubs: *Combretum hereroense*, *Grewia bicolor*, *G. monticola*, *Strychnos pungens*. Low Shrubs: *Agathisanthemum bojeri* (d), *Indigofera filipes* (d), *Felicia fascicularis*, *Gnidia sericocephala*. Geoxylic Suffrutex: *Dichapetalum cymosum* (d). Woody Climber: *Asparagus buchananii*. Graminoids: *Brachiaria nigropedata* (d), *Eragrostis pallens* (d), *E. rigidior* (d), *Hyperthelia dissoluta* (d), *Panicum maximum* (d), *Perotis patens* (d), *Anthephora pubescens*, *Aristida scabrivalvis* subsp. *scabrivalvis*, *Brachiaria serrata*, *Elionurus muticus*, *Eragrostis nindensis*, *Loudetia simplex*, *Schmidtia pappophoroides*, *Themeda triandra*, *Trachypogon spicatus*. Herbs: *Dicerocaryum senecioides* (d), *Barleria macrostegia*, *Blepharis integrifolia*, *Crabbea angustifolia*, *Evolvulus alsinoides*, *Geigeria burkei*, *Hermannia lancifolia*, *Indigofera daleoides*, *Justicia anagalloides*, *Kyphocarpa angustifolia*, *Lophiocarpus tenuissimus*, *Waltheria indica*, *Xerophyta humilis*. Geophytic

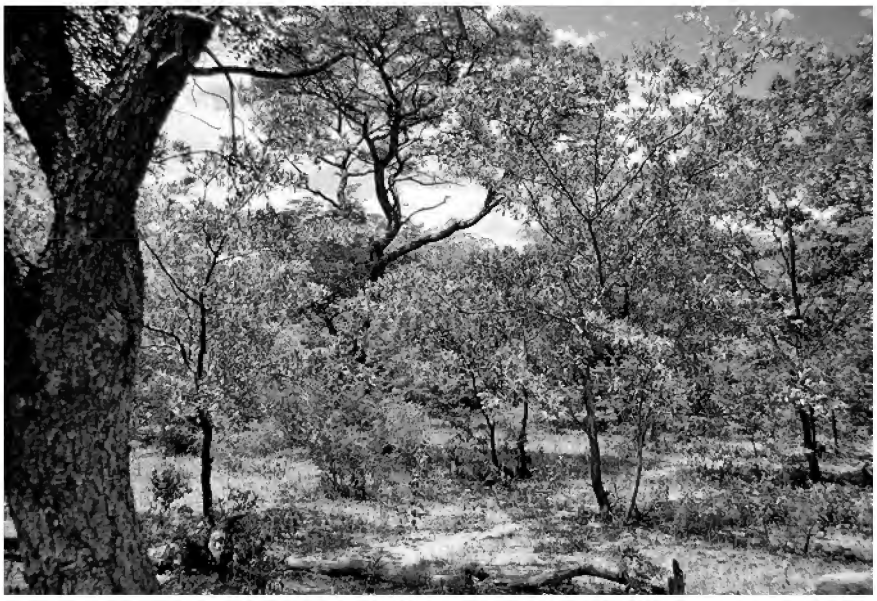

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Figure 9.21 SVcb 12 Central Sandy Bushveld: Open savanna dominated by *Burkea africana* and *Terminalia sericea* on a sandy ridge south of Mookgophong (Naboomspruit).

Herb: *Hypoxis hemerocallidea*. Succulent Herb: *Aloe greatheadii* var. *davyana*.

Biogeographically Important Taxa (Central Bushveld endemics) Graminoid: *Mosdenia leptostachys*. Herb: *Oxygonum dregeanum* subsp. *canescens* var. *dissectum*.

Conservation Vulnerable. Target 19%. Less than 3% statutorily conserved spread thinly across many nature reserves including the Doorndraai Dam and Skuinsdraai Nature Reserves. An additional 2% conserved in other reserves including the Wallmansthal SANDF Property and a grouping of private reserves, which include most of the Nylsvlei freshwater wetlands. About 24% transformed, including about 19% cultivated and 4% urban and built-up areas. Much of the unit in the broad arc south of the Springbokvlakte is heavily populated by rural communities. Several alien plants are widely scattered but often at low densities; these include *Cereus jamacaru*, *Eucalyptus* species, *Lantana camara*, *Melia azedarach*, *Opuntia ficus-indica* and *Sesbania punicea*. Erosion very low to high, especially in some places northeast of Groblersdal.

Remarks *Acacia sieberiana* occurs in the transition zone with grassland in the east, while *A. caffra* and *Faurea saligna* are dominant in the transition zone to SVcb 17 Waterberg Mountain Bushveld in the western parts of this unit. Central Sandy Bushveld is similar to SVcb 16 Western Sandy Bushveld, but the former is generally moister and cooler and generally lacks species such as *A. erubescens* and *A. nigrescens*. The climate seasons described above also apply to many other vegetation units of the Central Bushveld Bioregion. This vegetation unit includes probably the most intensively studied South African savanna field site of the South African Savanna Ecosystem Programme in the Nylsvley Nature Reserve (Limpopo Province).

References Grunow (1965), Coetzee et al. (1976), Van der Meulen (1979), Van der Meulen & Westfall (1980), Lubke et al. (1983), Lubke & Thatcher (1983), Scholes & Walker (1993), Dörgeloh (1998, 1999a, b).

SVcb 13 Loskop Mountain Bushveld

VT 18 Mixed Bushveld (49%), VT 19 Sourish Mixed Bushveld (47%) (Acocks 1953). LR 18 Mixed Bushveld (61%) (Low & Rebelo 1996).

Distribution Mpumalanga, Gauteng and Limpopo Provinces: Occurs on mountains in the vicinity of Loskop Dam extending southwestwards towards Bronkhorstspruit on mountains including the Gouwsberge and westwards to Rust de Winter on mountains including Ditlhabane. Altitude about 1 050–1 500 m.

Vegetation & Landscape Features Low mountains and ridges with open tree savanna on lower-lying areas dominated by *Burkea africana* and a denser broad-leaved tree savanna on lower slopes and midslopes with prominent *Diplorhynchus condylocarpon*, *Combretum apiculatum* and *Acacia caffra*. Herbaceous layer is dominated by grasses.

Geology & Soils Rhyolite of the Selons River Formation (Rooiberg Group, Transvaal Supergroup) and sandstone with subordinate conglomerate and minor shale of the Wilge River Formation (Mokolian Waterberg Group) are most abundant. The Rashoop Granophyre Suite and granite of the Lebowa Granite Suite, (both Bushveld Igneous Complex, Vaalian) are also represented, as are some mudrock, sandstone, conglomerate and volcanic rocks of the Loskop Formation (Vaalian Transvaal Supergroup). Rocky areas with miscellaneous soils

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Figure 9.22 SVcb 13 Loskop Mountain Bushveld: Open broad-leaved woodland occurring on mountain slopes with *Rhynchosia nervosa*, *Mundulea sericea*, *Combretum molle* and *C. zeyheri* in the Loskop Dam Nature Reserve.

ranging from sandy to sandy loams, sandy clays and some clays. Land type is mainly Ib.

Climate Summer rainfall with very dry winters. Frost fairly infrequent. MAP about 600–750 mm. See also climate diagram for SVcb 13 Loskop Mountain Bushveld.

Important Taxa Tall Tree: *Acacia burkei*. Small Trees: *Acacia caffra* (d), *Burkea africana* (d), *Combretum apiculatum* (d), *C. zeyheri* (d), *Croton gratissimus* (d), *Faurea saligna* (d), *Heteropyxis natalensis* (d), *Ochna pulchra* (d), *Protea caffra* (d), *Pseudolachnostylis maprouneifolia* (d), *Terminalia sericea* (d), *Brachylaena rotundata*, *Combretum molle*, *Englerophytum magalismontanum*, *Ozoroa sphaerocarpa*, *Pappea capensis*, *Rhus leptodictya*, *Strychnos cocculoides*, *Vangueria parvifolia*. Tall Shrubs: *Diplorhynchus condylocarpon* (d), *Elephantorrhiza burkei* (d), *Combretum moggii*, *Grewia flava*, *Mundulea sericea*, *Pavetta zeyheri*, *Psydrax livida*, *Vitex rehmannii*. Low Shrub: *Rhus zeyheri* (d). Succulent Shrub: *Aloe castanea*. Graminoids: *Aristida transvaalensis* (d), *Loudetia simplex* (d), *Trachypogon spicatus* (d), *Digitaria eriantha* subsp. *eriantha*, *Enneapogon pretoriensis*, *Heteropogon contortus*, *Setaria sphacelata*, *Themeda triandra*, *Tristachya biseriata*. Herb: *Xerophyta retinervis*.

Endemic Taxa Geophytic Herb: *Gladiolus pole-evansii*. Succulent Herb: *Haworthia koelmaniorum*.

Conservation Least threatened. Target 24%. About 15% statutorily conserved mainly in the Loskop Dam and Mabusa Nature Reserves. About 2% additionally conserved in other reserves. Less than 3% transformed mainly by cultivation and urban and built-up areas. Erosion is mostly very low to low.

Remark The great variation in geology and topography in the area is associated with a wide variety of plant communities.

Reference Theron (1973).

SVcb 14 Loskop Thornveld

VT 18 Mixed Bushveld (91%) (Acocks 1953). LR 18 Mixed Bushveld (71%) (Low & Rebelo 1996).

Distribution Mpumalanga Province and very marginally into Limpopo Province: South of Groblersdal, the valley of the Bloed River towards Stoffberg and the valley of the Olifants River to the Loskop Dam as well as valleys west of Groblersdal to Dennilton. Altitude about 950–1 300 m.

Vegetation & Landscape Features Valleys and plains of parts of the upper Olifants River catchment. Open, deciduous to semideciduous, tall, thorny woodland, usually dominated by *Acacia* species.

Geology & Soils Gabbro, norite and anorthosite of the Dsjate Subsuite, olivine diorite, magnetite gabbro and gabbronorite of the Roossenekal Subsuite (both Rustenburg Layered Suite, Bushveld Igneous Complex), mudstone siltstone, sandstone, andesitic lava and carbonates of the Bloempoort Formation, mudstone, sandstone, conglomerate and volcanic rocks of the Loskop Formation (both Transvaal Supergroup, Vaalian Erathem), and granophyre of the Rashoop Granophyre Suite, also of Bushveld (Vaalian Erathem). Soils are vertic, melanic clays, plinthic catena, eutrophic and widespread red soils. Red-yellow apedal, freely drained soils, high base status. Deep soils with Hutton, Rensburg and Arcadia forms are common. Land types mainly Ea, Bc and Ae.

Climate Summer rainfall with very dry winters. MAP about 550–650 mm. Frost fairly infrequent. Mean monthly maximum and minimum temperatures for Loskop Dam-Irr are 35.7°C and 3.6°C for January and July, respectively. See also climate diagram for SVcb 14 Loskop Thornveld.

Important Taxa Tall Trees: *Acacia burkei*, *Sclerocarya birrea* subsp. *caffra*. Small Trees: *Acacia gerrardii* (d), *A. sieberiana* var. *woodii* (d), *A. nilotica*, *A. tortilis* subsp. *heteracantha*, *Berchemia zeyheri*, *Combretum zeyheri*, *Pappea capensis*, *Peltophorum africanum*, *Rhus leptodictya*. Tall Shrubs: *Euclea crispa* subsp. *crispa* (d), *Rhus pyroides* var. *pyroides* (d), *Dichrostachys cinerea*, *Euclea undulata*, *Grewia flava*, *Olea europaea* subsp. *africana*. Low Shrubs: *Asparagus suaveolens*, *Leonotis ocymifolia*, *Orthosiphon fruticosus*, *Vernonia poskeana* subsp. *botswanica*. Succulent Shrub: *Kalanchoe paniculata*. Woody Climber: *Clematis brachiata* (d). Woody Succulent Climber: *Senecio pleistocephalus*. Herbaceous Climber: *Rhynchosia minima* (d). Graminoids: *Bothriochloa insculpta* (d), *Digitaria argyrograpta* (d), *Themeda triandra* (d), *Aristida congesta*, *Bulbostylis humilis*, *Cenchrus ciliaris*, *Cymbopogon nardus*, *Enneapogon scoparius*, *Eragrostis trichophora*, *Eustachys paspaloides*, *Setaria verticillata*. Herb: *Kyphocarpa angustifolia*.

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Figure 9.23 SVcb 14 Loskop Thornveld: Deciduous open woodland occurring in valleys with dominant species including *Acacia sieberiana*, *A. tortilis* and *A. theronii*, east of Loskop Dam.

Biogeographically Important Taxon (Broadly disjunct distribution) Small Tree: *Acacia theronii* (d).

Conservation Vulnerable. Target 19%. About 11% statutorily conserved in the Loskop Dam Nature Reserve (with an additional 3.2% represented by the water surface of the reservoir). About a quarter of the area already transformed, mainly for agricultural crops requiring irrigation. The most common crops include maize, cotton, citrus, grapes and wheat (winter crop). There has been a dramatic increase in the establishment of vineyards. Old lands are invaded by *Acacia tortilis* and *Hyparrhenia hirta*. Alien plants, for example *Cereus jamacaru*, *Opuntia ficus-indica*, *Melia azedarach*, *Lantana camara* and *Solanum seaforthianum*, have invaded various parts of this unit. Erosion is generally moderate to very low.

Reference Theron (1973).

SVcb 15 Springbokvlakte Thornveld

VT 12 Springbok Flats Turf Thornveld (48%), VT 18 Mixed Bushveld (42%) (Acocks 1953). LR 14 Clay Thorn Bushveld (55%) (Low & Rebelo 1996).

Distribution Limpopo, Mpumalanga, North-West and Gauteng Provinces: Flats from Zebediela in the northeast to Hammanskraal and Assen in the southwest as well as from Bela-Bela and Mookgophong in the northwest to Marble Hall and Rust de Winter in the southeast. Altitude about 900–1 200 m.

Vegetation & Landscape Features Open to dense, low thorn savanna dominated by *Acacia* species or shrubby grassland with a very low shrub layer. Occurs on flat to slightly undulating plains.

Geology & Soils Rocks are part of the volcano-sedimentary Karoo Supergroup. Most abundant in the area are the mafic volcanics (tholeitic and olivine basalts and nephelinites) of the Letaba Formation, then the mudstones of the Irrigasie Formation and the shale, with sandstone units, of the Ecca Group. Soils are red-yellow apedal, freely drained with high base status and self-mulching, black, vertic clays. The vertic soils, with a fluctuating water table, experience prolonged periods of swelling and shrinking during wet and dry periods, considerable soil cracking when dry, a loose soil surface, high calcium carbonate content and gilgai micro-relief. Land types mainly Ae and Ea.

Climate Summer rainfall with very dry winters. MAP about 500–650 mm. Frost fairly infrequent in winter. Mean monthly maximum and minimum temperatures for Warmbaths–Towoomba are 35.2°C and –2.0°C for October and July, respectively. Corresponding values are 36.8°C and –1.2°C for Marble Hall for January and June, respectively. See also climate diagram for SVcb 15 Springbokvlakte Thornveld.

Important Taxa Small Trees: *Acacia karroo* (d), *A. luederitzii* var. *retinens* (d), *A. mellifera* subsp. *detinens* (d), *A. nilotica* (d), *Ziziphus mucronata* (d), *Acacia tortilis* subsp. *heteracantha*, *Boscia foetida* subsp. *rehmanniana*. Tall Shrubs: *Euclea undulata* (d), *Rhus engleri* (d), *Dichrostachys cinerea*, *Diospyros lycioides* subsp. *lycioides*, *Grewia flava*, *Tarchonanthus camphoratus*. Low Shrubs: *Acacia tenuispina* (d), *Ptycholobium plicatum*. Succulent Shrub: *Kleinia longiflora*. Herbaceous Climbers: *Momordica balsamina*, *Rhynchosia minima*. Graminoids: *Aristida bipartita* (d), *Dichanthium annulatum* var. *papillosum* (d), *Ischaemum afrum* (d), *Setaria incrassata* (d), *Aristida canescens*, *Brachiaria eruciformis*. Herbs: *Aspilia mossambicensis*, *Indigastrum parviflorum*, *Nidorella hottentotica*, *Orthosiphon suffrutescens*, *Senecio apiifolius*.

Biogeographically Important Taxon (Central Bushveld endemic) Graminoid: *Mosdenia leptostachys*.

Conservation Endangered. Target 19%. Only 1% statutorily conserved, mainly in the Mkombo Nature Reserve. Roughly three times this area is conserved in a number of other reserves. At least 49% transformed, including about 45% cultivated and 3% urban and built-up. Dense rural populations in parts of the southern and eastern side of the unit. Very scattered alien plants over wide areas include *Cereus jamacaru*, *Eucalyptus* species, *Lantana camara*, *Melia azedarach*, *Opuntia ficus-indica* and *Sesbania punicea*. Erosion is very low to moderate.

Remark The high clay content of the soil increases soil moisture stress and SVcb 15 Springbokvlakte Thornveld is more xeric than adjacent vegetation units (except for SVcb 27 Sekhukhune Plains Bushveld in the extreme northeast).

References Galpin (1926), Coetzee et al. (1976), Van der Meulen (1979), Van der Meulen & Westfall (1980), Winterbach (1998).

SVcb 16 Western Sandy Bushveld

VT 18 Mixed Bushveld (58%) (Acocks 1953). LR 18 Mixed Bushveld (75%) (Low & Rebelo 1996).

Distribution Limpopo and North-West Provinces: Occurs on flats and undulating plains from Assen northwards past Thabazimbi and remaining west of the Waterberg Mountains towards Steenbokpan in the north. Some patches occur between the Crocodile and Marico Rivers to the west. Mostly at altitudes of 900–1 200 m

Vegetation & Landscape Features Varies from tall open woodland to low woodland, broad-leaved as well as microphyllous tree species prominent. Dominant species include *Acacia erubescens* on flat areas, *Combretum apiculatum* on shallow soils of gravelly upland sites and *Terminalia sericea* on deep sands. Occurs on slightly undulating plains.

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Figure 9.24 SVcb 15 Springbokvlakte Thornveld: Open savanna dominated by *Acacia nilotica*, *A. tortilis* and *A. karroo* on turf flats on Uitzicht northeast of Roedtan at an altitude of 985 m. Cleared land for crops, typically encountered in this unit, is visible in the background.

Geology & Soils Sandstone and mudstone of the Matlabas Subgroup and sandstone, subordinate conglomerate, siltstone and shale of the Kransberg Subgroup (both Mokolian Waterberg Group) are found in the north. Archaean granite and gneiss of the Swazian Erathem and granite of the Lebowa Granite Suite (Bushveld Igneous Complex) are found in the west and southeast of the area, respectively. Soils are plinthic catena, eutrophic, red-yellow apedal, freely drained, high base status, Hutton and Clovelly with some Glenrosa and Mispah soil forms. Several areas have less sandy soil than that of SVcb 12 Central Sandy Bushveld. Land types mainly Bd, Ah, Ae and Fa.

Climate Summer rainfall with very dry winters. MAP from about 450 mm in the north to about 650 mm in the south. Fairly frequent light frost in winter. Mean monthly maximum and minimum tem-

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Figure 9.25 SVcb 16 Western Sandy Bushveld: Open bushveld dominated by *Combretum apiculatum, Acacia nigrescens* and *Sporobolus* species on Ruigtevley, Thabazimbi District.

peratures for Thabazimbi 36.0°C and –3.7°C for February and June, respectively. See also climate diagram for SVcb 16 Western Sandy Bushveld.

Important Taxa Tall Trees: *Acacia erioloba*, *A. nigrescens*, *Sclerocarya birrea* subsp. *caffra*. Small Trees: *Acacia erubescens* (d), *A. mellifera* subsp. *detinens* (d), *A. nilotica* (d), *A. tortilis* subsp. *heteracantha* (d), *Combretum apiculatum* (d), *C. imberbe* (d), *Terminalia sericea* (d), *Combretum zeyheri*, *Lannea discolor*, *Ochna pulchra*, *Peltophorum africanum*. Tall Shrubs: *Combretum hereroense* (d), *Euclea undulata* (d), *Coptosperma supra-axillare*, *Dichrostachys cinerea*, *Grewia bicolor*, *G. flava*, *G. monticola*. Low Shrubs: *Clerodendrum ternatum*, *Indigofera filipes*, *Justicia flava*. Graminoids: *Anthephora pubescens* (d), *Digitaria eriantha* subsp. *eriantha* (d), *Eragrostis pallens* (d), *E. rigidior* (d), *Schmidtia pappophoroides* (d), *Aristida congesta*, *A. diffusa*, *A. stipitata* subsp. *graciliflora*, *Eragrostis superba*, *Panicum maximum*, *Perotis patens*. Herbs: *Blepharis integrifolia*, *Chamaecrista absus*, *Evolvulus alsinoides*, *Geigeria burkei*, *Kyphocarpa angustifolia*, *Limeum fenestratum*, *L. viscosum*, *Lophiocarpus tenuissimus*, *Monsonia angustifolia*.

Conservation Least threatened. Target 19%. About 6% statutorily conserved, just over half of which in the Marakele National Park. About 4% transformed, mainly by cultivation. Erosion is generally low to very low.

Remark This unit is drier than the SVcb 12 Central Sandy Bushveld vegetation unit and is distinguished from it by the presence of such species as *Acacia erubescens*, *A. nigrescens* and *Combretum imberbe* and general absence of species such as *Burkea africana* and *Ochna pulchra*.

References Herbst (1973), Peel et al. (1991), Brown & Bredenkamp (1994), Brown et al. (1995, 1996, 1997), Winterbach (1998), Winterbach et al. (2000).

SVcb 17 Waterberg Mountain Bushveld

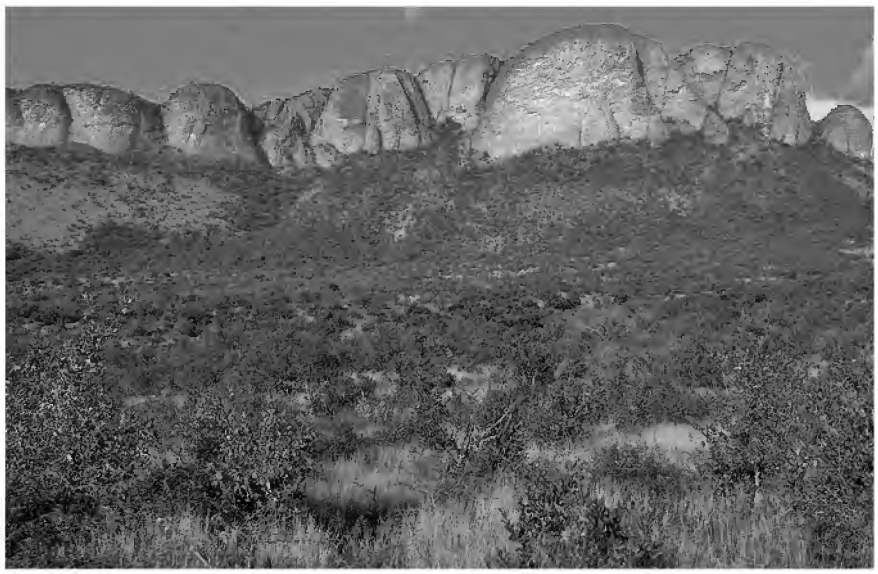
VT 20 Sour Bushveld (73%) (Acocks 1953). LR 12 Waterberg Moist Mountain Bushveld (83%) (Low & Rebelo 1996).

Distribution Limpopo Province: Waterberg Mountains, including the foothills, escarpment and tablelands south of the line between Lephalale and Marken and north of Bela-Bela and west of Mokopane and with outliers in the southwest such as the Boshofsberge and Vlieëpoortberge near Thabazimbi. Altitude about 1 000–1 600 m and generally at a lower altitude than the Gm 29 Waterberg-Magaliesberg Summit Sourveld.

Vegetation & Landscape Features Rugged mountains with vegetation grading from *Faurea saligna–Protea caffra* bushveld on higher slopes (in turn grading into the Gm 29 Waterberg-Magaliesberg Summit Sourveld) through broad-leaved deciduous bushveld (dominated by *Diplorhynchus condylocarpon*) on rocky mid- and footslopes to *Burkea africana–Terminalia sericea* savanna in the lower-lying valleys as well as on deeper sands of the plateaus. The grass layer is moderately developed or well developed.

Geology & Soils Mainly sandstone, subordinate conglomerate, siltstone and shale of the Kransberg Subgroup and medium- to coarse-grained sandstone, conglomerate, trachytic lava and quartz porphyry of the Swaershoek Formation, Nylstroom Subgroup (both Mokolian Waterberg Group). Dystrophic, acidic sandy, loamy to gravelly soil. Glenrosa and Mispah Forms. Land types mainly Ib, Ac, Fa and Ad.

Climate Summer rainfall with very dry winters. MAP from about 500 mm in the lower-altitude northwest to about 750 mm on the higher parts of the main east-west range. Frost fairly frequent in winter. See also climate diagram for SVcb 17 Waterberg Mountain Bushveld.



M.C. Rutherford

Figure 9.26 SVcb 17 Waterberg Mountain Bushveld: West-facing slopes with *Combretum apiculatum, Dichrostachys cinerea* and *Grewia monticola* at 1 235 m within the Marakele National Park, Thabazimbi District.

Important Taxa Tall Tree: *Acacia robusta*. Small Trees: *Acacia caffra* (d), *Burkea africana* (d), *Combretum apiculatum* (d), *Croton gratissimus* (d), *Cussonia transvaalensis* (d), *Faurea saligna* (d), *Heteropyxis natalensis* (d), *Ochna pulchra* (d), *Protea caffra* (d), *Albizia tanganyicensis*, *Combretum molle*, *Englerophytum magalismontanum*, *Ficus burkei*, *F. glumosa*, *Ochna pretoriensis*, *Pseudolachnostylis maprouneifolia*, *Rhus lancea*, *Terminalia sericea*, *Vangueria infausta*, *V. parvifolia*. Tall Shrubs: *Diplorhynchus condylocarpon* (d), *Elephantorrhiza burkei* (d), *Combretum moggii*, *C. nelsonii*, *Dichrostachys cinerea*, *Euclea crispa* subsp. *crispa*, *Gnidia kraussiana*, *Olea capensis* subsp. *enervis*, *O. europaea* subsp. *africana*, *Rhus pyroides* var. *pyroides*, *Strychnos pungens*, *Vitex rehmannii*. Low Shrubs: *Anthospermum rigidum* subsp. *rigidum*, *Barleria affinis*, *Felicia muricata*, *Helichrysum kraussii*, *Protea welwitschii* subsp. *welwitschii*, *Rhus rigida* var. *dentata*. Geoxylic Suffrutices: *Dichapetalum cymosum*, *Parinari capensis* subsp. *capensis*. Succulent Shrubs: *Aloe chabaudii*, *Lopholaena coriifolia*. Woody Climbers: *Ancylobotrys capensis* (d), *Rhoicissus revoilii*. Graminoids: *Loudetia simplex* (d), *Schizachyrium sanguineum* (d), *Trachypogon spicatus* (d), *Brachiaria serrata*, *Digitaria eriantha* subsp. *eriantha*, *Elionurus muticus*, *Enneapogon scoparius*, *Setaria sphacelata*, *Themeda triandra*, *Tristachya leucothrix*. Herbs: *Berkheya insignis*, *Chamaecrista mimosoides*, *Geigeria elongata*, *Hibiscus meyeri* subsp. *transvaalensis*, *Xerophyta retinervis*. Geophytic Herbs: *Haemanthus humilis* subsp. *humilis*, *Hypoxis rigidula*.

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Figure 9.27 SVcb 18 Roodeberg Bushveld: Moderately dense bushveld dominated by *Kirkia acuminata*, *Combretum apiculatum*, *Dichrostachys cinerea*, *Terminalia sericea* and *Acacia* species on the Farm Goedgedacht west of Marken in the Mokopane District.

Biogeographically Important Taxa ([CB]Central Bushveld endemic, [N]Northern Sourveld endemic) Small Tree: *Encephalartos eugene-maraisii*[N]. Tall Shrub: *Erythrophysa transvaalensis*[CB]. Soft Shrub: *Chorisochora transvaalensis*[N]. Graminoid: *Mosdenia leptostachys*[CB].

Endemic Taxa Tall Shrubs: *Grewia rogersii*, *Pachystigma triflorum*. Herb: *Oxygonum dregeanum* subsp. *canescens* var. *pilosum*.

Conservation Least threatened. Target 24%. About 9% statutorily conserved mainly in the Marakele National Park and Moepel Nature Reserve. More than 3% transformed, mainly by cultivation. Human population density is low. Erosion is generally very low to low.

Remark Carrying capacity of the vegetation for domestic stock animals is low, especially during the dry season.

References Coetzee et al. (1981), Westfall (1981), Westfall et al. (1983, 1985), Ben-Shahar (1988), Van Staden (2002), Van Staden & Bredenkamp (2005).

SVcb 18 Roodeberg Bushveld

VT 18 Mixed Bushveld (65%) (Acocks 1953). LR 18 Mixed Bushveld (60%) (Low & Rebelo 1996).

Distribution Limpopo Province: Straddling the Tropic of Capricorn, occurs from Marken and Villa Nora in the south through Baltimore to near Swartwater in the north and to the plains around the base of the Blouberg and Lerataupje Mountains in the northeast. Altitude about 850–1 100 m.

Vegetation & Landscape Features Plains and slightly undulating plains, including some low hills, with short closed woodland to tall open woodland and poorly developed grass layer. *Kirkia acuminata* trees not limited to hills.

Geology & Soils Mainly sandstone, conglomerate, siltstone and shale of the Kransberg and Matlabas Subgroups (Mokolian Waterberg Group). Gneisses, metasediments and metavolcanic rocks of the Malala Drift Group, Beit Bridge Complex (Swazian Erathem) occur in the north. Granite of the Lebowa Granite Suite (Bushveld Igneous Complex) is also present. A variety of soil types, but mostly sandy soils, red-yellow apedal high base status, also dystrophic or mesotrophic. Almost half the area is Ae land type, with remainder divided between mainly Fa, Bc, Ac, Fc, Ia and Fb.

Climate Summer rainfall with very dry winters. MAP 400–550 mm. Frost fairly infrequent. Mean monthly maximum and minimum temperatures for Marnitz 37.1°C and 0.2°C for November and June, respectively. See also climate diagram for SVcb 18 Roodeberg Bushveld.

Important Taxa Tall Trees: *Acacia burkei* (d), *A. nigrescens* (d), *A. robusta* (d), *A. erioloba*, *Sclerocarya birrea* subsp. *caffra*. Small Trees: *Acacia erubescens* (d), *A. mellifera* subsp. *detinens* (d), *A. nilotica* (d), *A. tortilis* subsp. *heteracantha* (d), *Combretum apiculatum* (d), *Kirkia acuminata* (d), *Acacia grandicornuta*, *A. luederitzii* var. *retinens*, *A. senegal* var. *leiorhachis*, *Albizia harveyi*, *Combretum imberbe*, *Commiphora mollis*, *Rhus lancea*, *Terminalia sericea*, *Ziziphus mucronata*. Tall Shrubs: *Dichrostachys cinerea* (d), *Grewia flava* (d), *Euclea crispa* subsp. *crispa*, *E. undulata*, *Grewia monticola*, *Hibiscus micranthus*. Low Shrubs: *Commiphora africana*, *Melhania acuminata*, *Sida cordifolia*, *Solanum delagoense*. Graminoids: *Aristida canescens* (d), *Chloris virgata* (d), *Digitaria eriantha* subsp. *eriantha* (d), *Enneapogon cenchroides* (d), *Eragrostis rigidior* (d), *Panicum maximum* (d), *Urochloa mosambicensis* (d), *Aristida congesta*, *Brachiaria deflexa*, *Cymbopogon pospischilii*, *Cynodon dactylon*, *Eragrostis rotifer*. Herbs: *Achyranthes aspera*, *Corbichonia decumbens*, *Hemizygia elliottii*, *Kyphocarpa angustifolia*, *Seddera capensis*, *Tephrosia purpurea* subsp. *leptostachya*, *Waltheria indica*.

Conservation Least threatened. Target 19%. Almost 6% statutorily conserved, mainly in the Wonderkop and Blouberg (Malebocho) Nature Reserves. An additional 3% conserved in other reserves, mainly in areas adjacent to the Wonderkop Nature Reserve. About 18% transformed, mainly by cultivation, with very little urban and built-up areas. Erosion is low to high. The area is mostly used for game ranching.

References Schmidt et al. (1993, 1994), Schulze et al. (1994), Winterbach (1998), J.M. van Staden (unpublished data).

SVcb 19 Limpopo Sweet Bushveld

VT 14 Arid Sweet Bushveld (74%) (Acocks 1953). LR 17 Sweet Bushveld (65%) (Low & Rebelo 1996).

Distribution Limpopo Province: Extends from the lower reaches of the Crocodile and Marico Rivers around Makoppa and Derdepoort, respectively, down the Limpopo River Valley including Lephalale and into the tropics past Tom Burke to the Usutu border post and Taaiboschgroet area in the north. Altitude about 700–1 000 m. The unit also occurs on the Botswana side of the border.

Vegetation & Landscape Features Plains, sometimes undulating or irregular, traversed by several tributaries of the Limpopo River. Short open woodland; in disturbed areas thickets of *Acacia erubescens*, *A. mellifera* and *Dichrostachys cinerea* are almost impenetrable.

Geology & Soils The northern half of the area is dominated by gneisses, metasediments and metavolcanics of the Malala Drift Group, Beit Bridge Complex (Swazian Erathem), basalts of the Letaba Formation (Lebombo Group of the Karoo Supergroup) are also found in the northeast. Sandstone, siltstone and mudstone of the Clarens Formation (Karoo Supergroup), as well as of the Matlabas Subgroup (Mokolian Waterberg Group) are found to the south and west. Soils with calcrete and surface limestone layers, brownish sandy (Clovelly soil form) clayey-loamy soils (Hutton soil form) on the plains and low-lying areas, with shallow, gravelly, sandy soils on the slightly undulating areas, localised areas of black clayey soils (Valsrivier or Arcadia soil forms) and Kalahari sand. Land types mainly Ae, Ah and Fc.

Climate Summer rainfall with very dry winters including the shoulder months of May and September. MAP from about 350 mm in the northeast to about 500 mm in the southwest. Frost fairly infrequent. Mean monthly maximum and minimum temperatures for Lephalale 38.2°C and 2.1°C for December and June, respectively. See also climate diagram for SVcb 19 Limpopo Sweet Bushveld.

Important Taxa Tall Trees: *Acacia robusta* (d), *A. burkei*. Small Trees: *Acacia erubescens* (d), *A. fleckii* (d), *A. nilotica* (d), *A. senegal* var. *rostrata* (d), *Albizia anthelmintica* (d), *Boscia albitrunca* (d), *Combretum apiculatum* (d), *Terminalia sericea*. Tall Shrubs: *Catophractes alexandri* (d), *Dichrostachys cinerea* (d), *Phaeoptilum spinosum* (d), *Rhigozum obovatum* (d), *Cadaba aphylla*, *Combretum hereroense*, *Commiphora pyracanthoides*, *Ehretia rigida* subsp. *rigida*, *Euclea undulata*, *Grewia flava*, *Gymnosporia senegalensis*. Low Shrubs: *Acacia tenuispina* (d), *Commiphora africana*, *Felicia muricata*, *Gossypium herbaceum* subsp. *africanum*, *Leucosphaera bainesii*. Graminoids: *Digitaria eriantha* subsp. *eriantha* (d), *Enneapogon cenchroides* (d), *Eragrostis lehmanniana* (d), *Panicum coloratum* (d), *Schmidtia pappophoroides* (d), *Aristida congesta*, *Cymbopogon nardus*, *Eragrostis pallens*, *E. rigidior*, *E. trichophora*, *Ischaemum afrum*, *Panicum maximum*, *Setaria verticillata*, *Stipagrostis uniplumis*, *Urochloa mosambicensis*. Herbs: *Acanthosicyos naudinianus*, *Commelina benghalensis*, *Harpagophytum procumbens* subsp. *transvaalense*, *Hemizygia elliottii*, *Hermbstaedtia odorata*, *Indigofera daleoides*. Succulent Herbs: *Kleinia fulgens*, *Plectranthus neochilus*.

Biogeographically Important Taxon (Central Bushveld endemic) Succulent Herb: *Piaranthus atrosanguineus.*

Conservation Least threatened. Target 19%. Less than 1% statutorily conserved and limited to reserves straddling the southeastern limits of the unit, for example the D'Nyala Nature Reserve. Very little conserved in other reserves. About 5% transformed, mainly by cultivation. Erosion is low to high.

Remark Though limited by low rainfall, this is a good area for game and cattle farming due to the high grazing capacity of sweet veld.

References Bosch (1971), Herbst (1973), Panagos et al. (1986), Pauw (1988), Peel (1990), Van Staden (1991).

SVcb 20 Makhado Sweet Bushveld

VT 18 Mixed Bushveld (51%) (Acocks 1953). LR 18 Mixed Bushveld (44%), LR 17 Sweet Bushveld (43%) (Low & Rebelo 1996).

M.C. Rutherford

Figure 9.28 SVcb 19 Limpopo Sweet Bushveld: Open bushveld dominated by *Acacia senegal* at 740 m on the Farm Kwarel between Maasstroom and Alldays (Limpopo Province).

Distribution Limpopo Province: Straddling the Tropic of Capricorn, occurs on the plains south of the Soutpansberg, east of the Waterberg and on the apron surrounding the Blouberg and Lerataupje Mountains, and north of the Polokwane Plateau and west of the escarpment, with extensions to Mokopane to the south and to the north near Vivo. Altitude about 850–1 200 m.

Vegetation & Landscape Features Slightly to moderately undulating plains sloping generally down to the north, with some hills in the southwest. Short and shrubby bushveld with a poorly developed grass layer.

Geology & Soils The area is underlain by the gneisses and migmatites of the Hout River Gneiss (Randian Erathem) and the potassium-deficient gneisses

of the Goudplaats Gneiss (Swazian Erathem). Sandstones and mudstones of the Matlabas Subgroup (Mokolian Waterberg Group) are also found. Soils include deep, greyish sands, eutrophic plinthic catenas, red-yellow apedal freely drained soils with high base status, clayey in bottomlands. Land types mainly Bd, Bc, Ae and Ia.

Climate Summer rainfall with very dry winters. MAP about 350–550 mm. Frost fairly infrequent. Mean monthly maximum and minimum temperatures for Mara-Agr 36.5°C and –0.8°C for November and June, respectively. See also climate diagram for SVcb 20 Makhado Sweet Bushveld.

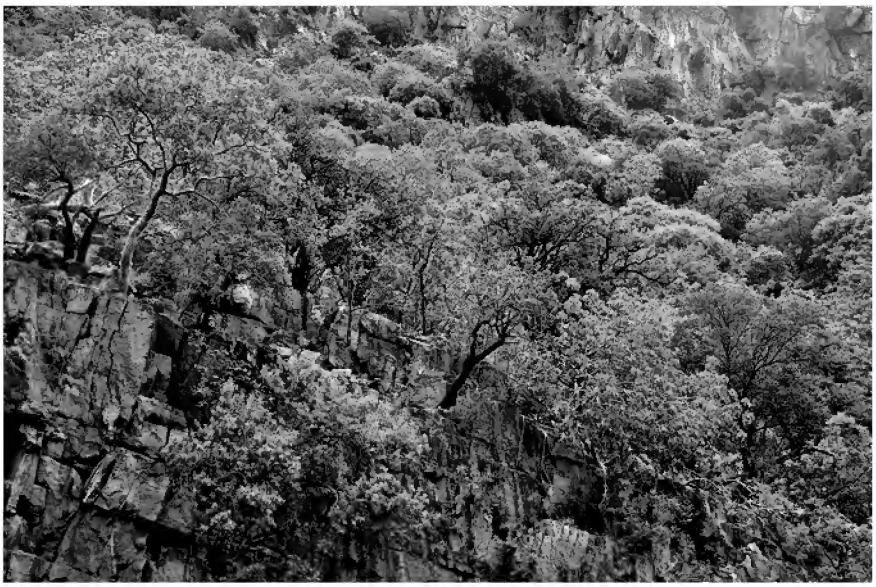
Important Taxa Small Trees: *Acacia erubescens* (d), *A. gerrardii* (d), *A. mellifera* subsp. *detinens* (d), *A. rehmanniana* (d), *Boscia albitrunca* (d), *Combretum apiculatum* (d), *Acacia tortilis* subsp. *heteracantha*, *Terminalia sericea*. Tall Shrubs: *Commiphora pyracanthoides*, *Dichrostachys cinerea*, *Grewia flava*, *Hibiscus calyphyllus*, *Lycium shawii*, *Rhigozum obovatum*. Low Shrubs: *Barleria lancifolia*, *Hirpicium bechuanense*, *Indigofera poliotes*, *Melhania rehmannii*, *Pechuel-Loeschea leubnitziae*. Graminoids: *Anthephora pubescens* (d), *Aristida stipitata* subsp. *graciliflora* (d), *Cenchrus ciliaris* (d), *Enneapogon scoparius* (d), *Brachiaria nigropedata*, *Eragrostis trichophora*, *Panicum coloratum*, *P. maximum*, *Schmidtia pappophoroides*, *Urochloa mosambicensis*. Herbs: *Chamaecrista absus*, *Corbichonia decumbens*, *Geigeria acaulis*, *Harpagophytum procumbens* subsp. *transvaalense*, *Heliotropium steudneri*, *Hemizygia elliottii*, *Hermbstaedtia odorata*, *Leucas sexdentata*, *Osteospermum muricatum*, *Tephrosia purpurea* subsp. *leptostachya*.

Endemic Taxon Herb: *Dicliptera minor* subsp. *pratis-manna*.

Conservation Vulnerable. Target 19%. About 1% statutorily conserved, mainly in the Bellevue Nature Reserve. Some 27% transformed, mainly by cultivation, with some urban and built-up areas. The southwestern half of the unit has densely populated rural communities. Erosion is low to high.

Remark This area is transitional between the higher-lying Polokwane Plateau and the lower-lying vegetation units of the Limpopo River Valley.

Reference Peel (1990).



L. Mucina

Figure 9.29 SVcb 21 Soutpansberg Mountain Bushveld: Sour bushveld on steep slopes of the Soutpansberg in the Wyllie's Poort north of Makhado, Limpopo Province.

SVcb 21 Soutpansberg Mountain Bushveld

VT 8 North-Eastern Mountain Sourveld (38%), VT 19 Sourish Mixed Bushveld (34%) (Acocks 1953). LR 21 Sour Lowveld Bushveld (56%) (Low & Rebelo 1996).

Distribution Limpopo Province: Occurs on the slopes of the Soutpansberg Mountain, and Blouberg and Leraataupje Mountains in the west. Extends eastward on lower ridges including Khaphamali and Makonde Mountains. Altitude about 600–1 500 m.

Vegetation & Landscape Features Low to high mountains, highest in the west, splitting into increasing number of lower mountain ridges towards the east. Dense tree layer and poorly developed grassy layer. The topography of the east-west-orientated ridges of the mountain changes drastically over short distances, resulting in orographic rain on the southern ridges, and a rainshadow effect on the northern ridges. Because of this topographic diversity, the Soutpansberg Mountain Bushveld comprises a complex mosaic of sharply contrasting kinds of vegetation within limited areas. The main vegetation variations within the Soutpansberg Mountain Bushveld are subtropical moist thickets (mainly along the lower-lying southern slopes, on steep clayey soils of volcanic origin), mistbelt bush clumps (within the mistbelt of the southern and central ridges of the mountain, on rugged quartzitic outcrops with shallow sandy soils), relatively open savanna sandveld (on both deep and shallow quarzitic sands along the relatively dry middle and northern slopes of the mountain), and arid mountain bushveld (along the very arid northern ridges of the mountain).

Geology & Soils Reddish or brown, sandstone and quartzite, conglomerate, basalt, tuff, shale and siltstone of the Soutpansberg Group (including the Wyllie's Poort, Fundudzi and Nzhelele Formations), Mokolian Erathem. Rocky areas with miscellaneous soils including acidic dystrophic to mesotrophic sandy to loamy soil. Glenrosa and Mispah soil forms are common. Land types mainly Ib, Ab, Fa, Fb, Ae and Ia.

Climate Summer rainfall with dry winters. MAP about 450–900 mm. Frost infrequent. See also climate diagram for SVcb 21 Soutpansberg Mountain Bushveld.

Important Taxa **Subtropical moist thickets:** Small Trees: *Catha edulis* (d), *Acacia karroo*, *Berchemia zeyheri*, *Bridelia mollis*, *Combretum molle*, *Dombeya rotundifolia*, *Dovyalis zeyheri*, *Kirkia acuminata*, *Mystroxylon aethiopicum* subsp. *schlechteri*, *Plectroniella armata*, *Zanthoxylum capense*, *Ziziphus mucronata*. Tall Shrubs: *Flueggea virosa* (d), *Carissa edulis*, *Grewia occidentalis*, *Rhus pentheri*. Low Shrub: *Pavonia burchellii*. **Mistbelt bush clumps:** Small Trees: *Englerophytum magalismontanum* (d), *Mimusops zeyheri* (d), *Syzygium legatii* (d), *Apodytes dimidiata* subsp. *dimidiata*, *Combretum molle*, *Heteropyxis natalensis*, *Maytenus undata*. Tall Shrubs: *Coddia rudis*, *Combretum moggii*, *Euclea linearis*, *Hyperacanthus amoenus*, *Olea capensis* subsp. *enervis*, *Vitex rehmannii*. Low Shrubs: *Rhus magalismontana* subsp. *coddii* (d), *Helichrysum kraussii*, *Heteromorpha stenophylla* var. *transvaalensis*, *Myrothamnus flabellifolius*. Geoxylic Suffrutex: *Parinari capensis* subsp. *capensis* (d). Succulent

Shrubs: *Aloe arborescens*, *Kalanchoe sexangularis*. Graminoids: *Coleochloa setifera* (d), *Setaria sphacelata* (d), *Melinis nerviglumis*, *Trachypogon spicatus*. Herbs: *Fadogia homblei* (d), *Dicoma anomala*, *Felicia mossamedensis*, *Gerbera viridifolia*, *Vernonia natalensis*. Succulent Herbs: *Crassula swaziensis*, *Plectranthus cylindraceus*. **Open savanna sandveld:** Small Trees: *Burkea africana* (d), *Ochna pulchra* (d), *Combretum apiculatum*, *Ochna pretoriensis*, *Pseudolachnostylis maprouneifolia*, *Terminalia sericea*. Tall Shrubs: *Corchorus kirkii*, *Diplorhynchus condylocarpon*, *Elephantorrhiza burkei*, *Strychnos madagascariensis*. Graminoids: *Centropodia glauca* (d), *Enneapogon cenchroides*. Herb: *Xerophyta retinervis* (d). **Arid mountain bushveld:** Tall Trees: *Acacia nigrescens*, *Adansonia digitata*. Small Trees: *Combretum apiculatum*, *Commiphora glandulosa*, *C. mollis*. Tall Shrub: *Tinnea rhodesiana*. Low Shrubs: *Blepharis diversispina*, *Gossypium herbaceum* subsp. *africanum*. Woody Climber: *Acacia ataxacantha*. Herb: *Hibiscus meyeri* subsp. *transvaalensis*. Succulent Herb: *Kleinia fulgens*.

E. van Wyk

Figure 9.30 SVcb 22 VhaVenda Miombo: Hillslopes with savanna dominated by *Brachystegia spiciformis* in the Mbodi River Valley (Soutpansberg), Limpopo Province.

Biogeographically Important Taxa (Soutpansberg endemics) Succulent Herbs: *Aloe vossii*, *Huernia whitesloaneana*, *Orbea conjuncta, Stapelia clavicorona*.

Endemic Taxa Tall Shrubs: *Combretum vendae*, *Vangueria soutpansbergensis*. Low Shrubs: *Blepharis spinipes*, *Dicoma montana*, *Justicia montis-salinarum*, *Tylophora coddii*. Succulent Shrub: *Kalanchoe crundallii*. Herbaceous Climber: *Ipomoea bisavium*. Graminoid: *Panicum dewinteri*. Herb: *Streptocarpus caeruleus*. Succulent Herbs: *Aloe swynnertonii*, *Huernia nouhuysii*.

Conservation Vulnerable. Target 24%. Just over 2% statutorily conserved in the Blouberg, Happy Rest and Nwanedi Nature Reserves. A smaller area is conserved in other reserves. Some 21% transformed, with about 14% cultivated and 6% plantations. High rural human population densities in some of the lower lying parts of the eastern section of the unit. Erosion is very low to moderate.

Remarks This unit is part of the Soutpansberg CE (Van Wyk & Smith 2001). The unit has patches of Northern Mistbelt Forest and Northern Escarpment Afromontane Fynbos embedded in its generally south-facing, upper elevation reaches in the central-western parts. Also embedded are patches of Soutpansberg Summit Sourveld, generally but not always, at elevations higher than the unit. VhaVenda Miombo is also embedded very locally at a lower elevation in the eastern part of the unit. Further research, particularly in the eastern section of this unit, may indicate a revision of this unit.

References Scholes (1979), Van Jaarsveld & Hardy (1991), Van Wyk & Smith (2001), N. Hahn (unpublished data), T.H.C. Mostert (unpublished data), C.H. Verwey (unpublished data).

SVcb 22 VhaVenda Miombo

VT 19 Sourish Mixed Bushveld (100%) (Acocks 1953). LR 11 Soutpansberg Arid Mountain Bushveld (100%) (Low & Rebelo 1996).

Distribution Limpopo Province: As far as is known, it is limited to a small area in the upper reaches of the Mbodi River Valley between Shakadaza and Mafukani within the eastern extension of SVcb 21 Soutpansberg Mountain Bushveld. Altitude about 750–850 m.

Vegetation & Landscape Features Moderately gentle to some steeper slopes with surface stone, in a narrow valley straddling a north-flowing section of the Mbodi River. Fragmented, archipelago of patches with tallest *Brachystegia spiciformis* trees toward the centres of the islands. Tree layer very broken and irregular cover of larger and smaller shrubs. Understorey is species-poor with mainly *Senecio barbertonicus* on deeper soils and *Cyanotis lapidosa* on the shallow soils. Very sparse ground cover with grasses virtually limited to streambanks.

Geology & Soils Sandstone and quartzite of the Wyllie's Poort Formation (Mokolian Soutpansberg Group). Shallow sand with rock and deeper sands in some places. Land type is Ib.

Climate Summer rainfall with very dry winters. MAP about 670–680 mm. Frost very infrequent. See also climate diagram for SVcb 22 VhaVenda Miombo.

Important Taxa Small Trees: *Afzelia quanzensis*, *Albizia adianthifolia*, *Berchemia discolor*, *Bridelia mollis*, *Burkea africana*, *Combretum collinum* subsp. *gazense*, *Englerophytum magalismontanum*, *Erythrina lysistemon*, *Ficus glumosa*, *F. sansibarica*, *F. sur*, *Parinari curatellifolia*, *Peltophorum africanum*, *Plectroniella armata*, *Syzygium cordatum*, *S. guineense*, *Tabernaemontana elegans*, *Ximenia caffra*, *Xylopia odoratissima*, *Zanthoxylum capense*, *Z. leprieurii*, *Ziziphus mucronata*. Succulent Trees: *Euphorbia confinalis*, *E. ingens*, *E. tirucalli*. Tall Shrubs: *Coddia rudis*, *Grewia flavescens*, *Hexalobus monopetalus*, *Lagynias dryadum*, *Strychnos madagascariensis*, *S. pungens*. Low Shrub: *Rhus magalismontana* subsp. *coddii*. Succulent Shrubs: *Senecio barbertonicus* (d), *Kalanchoe lanceolata*, *K. rotundifolia*, *K. sexangularis*. Woody Climbers: *Acacia schweinfurthii*, *Artabotrys brachypetalus*, *Bauhinia galpinii*, *Cissus quadrangularis*, *Tecoma capensis*. Herbaceous Climber: *Senecio tamoides*. Herbs: *Cyanotis lapidosa*, *Portulaca kermesina*. Geophytic Herbs: *Asplenium schelpei*, *Cheilanthes viridis* var. *glauca*, *Cyrtorchis praetermissa*, *Sansevieria aethiopica*, *S. hyacinthoides*. Succulent Herbs: *Aloe aculeata*, *Crassula lanceolata*. Epiphytic Succulent Herb: *Ansellia africana*.

Biogeographically Important Taxon (Southern distribution limit in South Africa) Small Tree: *Brachystegia spiciformis* (d).

Conservation The unit is not conserved. The village of Gundane is in very close proximity to and extends into the southern part of the unit. The vegetation is heavily impacted by grazing (with grass cover virtually zero), wood-collecting (with at least half of the *Brachystegia spiciformis* trees estimated to have been removed, also to allow for a *Eucalyptus* plantation; P.J.H. Hurter, personal communication) and slash agriculture, mainly maize and a type of *Solanum* used as a relish. The alien *Opuntia ficus-indica* is common. A popular ecotourism lodge is situated within the unit.

Remarks *Brachystegia spiciformis* is one of the most important dominant species of miombo woodlands typical of southern, central and parts of eastern Africa, where they cover more than 2.7 million km^2. The occurrence of this species in South Africa was scientifically ascertained only recently (Van Wyk & Hurter 2000). It has been previously known from pollen records dated 19 000 years BP (Scott 1982) and its occurrence in the Soutpansberg (where it totals only a few thousand individuals) might be a relict of former larger distribution of miombo (see also Campbell 1996). Despite the assertion that these *Brachystegia spiciformis* patches do not constitute miombo relict vegetation (Hahn 2002), there are a number of species in the unit that occur in various miombo vegetation types to the north. These include: *Afzelia quanzensis*, *Albizia adianthifolia*, *Burkea africana*, *Combretum collinum*, *Parinari curatellifolia*, *Strychnos pungens*, *Syzygium guineense* and *Tabernaemontana elegans* (Werger & Coetzee 1978). The vegetation unit contains an unusually high proportion of succulent species compared to other miombo types. None of the Soutpansberg endemic species have been recorded in the unit.

References Van Wyk & Hurter (2000), Hurter & Van Wyk (2001), Willis et al. (2001), Hahn (2002).

SVcb 23 Polokwane Plateau Bushveld

VT 67 Pietersburg Plateau Grassveld (50%) (Acocks 1953). LR 18 Mixed Bushveld (88%) (Low & Rebelo 1996).

Distribution Limpopo Province: The higher-lying plains around Polokwane, north of the Strydpoort Mountains and south of the SVcb 20 Makhado Sweet Bushveld. Altitude about 1 100–1 500 m.

Vegetation & Landscape Features Moderately undulating plains with short open tree layer with a well-developed grass layer to grass plains with occasional trees at higher altitudes (for example the Mashashane area in the southwest and the south-eastern watershed of the Sand River catchment, such as around Eersteling). Hills and low mountains of SVcb 24 Mamabolo Mountain Bushveld are embedded within this unit.

Geology & Soils Migmatites and gneisses of the Hout River Gneiss and the Turfloop Granite (both of Randian Erathem) are dominant. Some ultramafic and mafic metavolcanics, quartzite and chlorite schist of the Pietersburg Group (Swazian Erathem) are also found. Soils variable, with freely drained soils with high base status, some dystrophic/mesotrophic, eutrophic plinthic catenas. Glenrosa and Mispah soil forms. Land types mainly Ae, Bd, Ah, Ab, Bc and Fa.

Climate Summer rainfall with very dry winters. MAP from about 400 mm in the northwest to about 600 mm where it borders on the foot of mountains to the east and south. Frost fairly infrequent. Mean monthly maximum and minimum temperatures for Polokwane 33.2°C and 0.6°C for October and June, respectively. See also climate diagram for SVcb 23 Polokwane Plateau Bushveld.

Important Taxa Small Trees: *Acacia caffra* (d), *A. permixta* (d), *A. rehmanniana* (d), *A. karroo*, *A. tortilis* subsp. *heteracantha*, *Combretum molle*, *Ormocarpum kirkii*, *Ziziphus mucronata*. Succulent Tree: *Aloe marlothii* subsp. *marlothii*. Tall Shrubs: *Acacia hebeclada* subsp. *hebeclada* (d), *Gymnosporia senegalensis* (d), *Combretum hereroense*, *Diospyros lycioides* subsp. *sericea*, *Euclea crispa* subsp. *crispa*, *Heteromorpha arborescens* var. *abyssinica*, *Lippia javanica*, *Rhus pyroides* var. *pyroides*, *Tephrosia rhodesica*, *Triumfetta pilosa* var. *tomentosa*. Low Shrubs: *Anthospermum rigidum* subsp. *rigidum*, *Gymnosporia glaucophylla*, *Hirpicium bechuanense*, *Lantana rugosa*, *Senecio burchellii*, *Sida rhombifolia*, *Solanum panduriforme*. Succulent Shrub: *Aloe cryptopoda*. Woody Climber: *Asparagus africanus*. Herbaceous Climbers: *Momordica balsamina*, *Rubia petiolaris*. Graminoids: *Aristida diffusa* (d), *Brachiaria nigropedata* (d), *Digitaria eriantha* subsp. *eriantha* (d), *Eragrostis curvula* (d), *Themeda triandra* (d), *Aristida congesta*, *Cymbopogon caesius*, *Cynodon dactylon*, *Digitaria diagonalis*, *Diheteropogon amplectens*, *Elionurus muticus*, *Eragrostis gummiflua*, *E. racemosa*, *E. superba*, *Eustachys paspaloides*, *Panicum maximum*, *Pogonarthria squarrosa*, *Sporobolus africanus*. Herbs: *Felicia mossamedensis*, *Hermbstaedtia odorata*, *Pollichia campestris*. Geophytic Herbs: *Eulophia petersii*, *Hypoxis hemerocallidea*. Succulent Herb: *Aloe greatheadii* var. *greatheadii*.

Biogeographically Important Taxa (Central Bushveld endemics) Graminoid: *Mosdenia leptostachys*. Herb: *Oxygonum dregeanum* subsp. *canescens* var. *dissectum*. Geophytic Herb: *Ledebouria crispa*.

Conservation Least threatened according to remote sensing sources, but with over one third of the remaining vegetation regarded as degraded, would probably be regarded as susceptable. Target 19%. Less than 2% statutorily conserved mainly in the Percy Fyfe and Kuschke Nature Reserves. In addition, 0.7% conserved in other reserves, for example the Polokwane Game Reserve. Some 17% transformed, including about 10% cul-

M.C. Rutherford

Figure 9.31 SVcb 23 Polokwane Plateau Bushveld: Very open savanna with low *Acacia tortilis* trees at an altitude of 1 250 m on Pilgrimshoop, north of Polokwane.

tivated and 6% urban and built-up. Dense concentration of rural human settlements is found particularly in the eastern and northwestern parts of the unit. In some regions, scattered populations of alien *Agave*, *Jacaranda mimosifolia*, *Melia azedarach*, *Opuntia ficus-indica* and *Ricinus communis* are of concern. Erosion is high to moderate.

Remark Woody plants have increased in parts of the unit in the past few decades.

References Bredenkamp & Van Vuuren (1977), Bredenkamp (1986b), Winterbach (1998).

SVcb 24 Mamabolo Mountain Bushveld

VT 19 Sourish Mixed Bushveld (43%), VT 8 North-Eastern Mountain Sourveld (32%) (Acocks 1953). LR 43 North-eastern Mountain Grassland (53%) (Low & Rebelo 1996).

Distribution Limpopo Province: East and south of the Polokwane Plateau along the foothills of the west-facing part of the eastern escarpment and of the Strydpoort and Makapan Mountains. Also on main isolated hills and small mountains embedded within the Polokwane Plateau as far as Mogoshi Mountain in the west and De Loskop (near Mogwadi) and Renosterkoppies (around Zandrivierspoort) to the north. Altitude mostly 1 200–1 600 m.

Vegetation & Landscape Features Low mountains, lower slopes of Strydpoort and Makapan ranges, and rocky hills. Slopes are moderate to steep, and very rocky, covered by small trees and shrubs. Rock slabs or domes are sparsely vegetated, and then mostly with a mixture of xerophytic or resurrection plants, with several succulents.

Geology & Soils Very varied geology includes basement granite and gneiss, clastic sediments of the Pretoria Group (Vaalian) and ultramafic and mafic metavolcanics of the Pietersburg Group (Swazian). Shallow and skeletal soil (including Mispah and Glenrosa soil forms). Land types mainly Ib and Fa.

Climate Summer rainfall with dry winters. MAP about 450–750 mm. Frost fairly infrequent. With the coolest mean annual temperature of all savanna units apart from the three mountain bushveld units of the Highveld. See also climate diagram for SVcb 24 Mamabolo Mountain Bushveld.

Important Taxa Tall Tree: *Sclerocarya birrea* subsp. *caffra*. Small Trees: *Combretum molle* (d), *Croton gratissimus* (d), *Heteropyxis natalensis* (d), *Acacia caffra*, *A. davyi*, *A. gerrardii*, *A. nilotica*, *Berchemia zeyheri*, *Cussonia natalensis*, *C. transvaalensis*, *Dombeya rotundifolia*, *Erythrina lysistemon*, *Lannea discolor*, *Maytenus undata*, *Pappea capensis*, *Rhus leptodictya*, *Schotia brachypetala*. Succulent Trees: *Euphorbia cooperi* (d), *Aloe marlothii* subsp. *marlothii*, *Euphorbia ingens*. Tall Shrubs: *Clerodendrum glabrum* (d), *Elephantorrhiza burkei* (d), *Acokanthera oppositifolia*, *A. rotundata*, *Buddleja saligna*, *Canthium mundianum*, *Carissa edulis*, *Ehretia obtusifolia*, *Euclea crispa* subsp. *crispa* (short, small-leaved form), *Grewia occidentalis*, *Hibiscus calyphyllus*, *Olea europaea* subsp. *africana*, *Pouzolzia mixta*, *Rhus pentheri*, *R. rehmanniana*, *Scutia myrtina*, *Tarchonanthus parvicapitulatus*. Low Shrubs: *Diospyros lycioides* subsp. *nitens* (d), *Grewia vernicosa* (d), *Barleria rotundifolia*, *Gossypium herbaceum* subsp. *africanum*, *Gymnosporia glaucophylla*, *Hermannia floribunda*, *Heteromorpha stenophylla* var. *transvaalensis*, *Lantana rugosa*, *Myrothamnus flabellifolius*, *Plinthus rehmannii*. Succulent Shrubs: *Kalanchoe sexangularis* (d), *Kleinia longiflora* (d), *Aloe arborescens*, *Cotyledon barbeyi*, *C. orbiculata* var. *orbiculata*, *Kalanchoe paniculata*, *K. rotundifolia*, *Senecio barbertonicus*, *Tetradenia riparia*. Woody Climbers: *Asparagus buchananii* (d), *Jasminum multipartitum* (d), *Acacia ataxacantha*, *Cryptolepis cryptolepidioides*. Herbaceous Climber: *Pentarrhinum insipidum*. Graminoids: *Cymbopogon caesius* (d), *Digitaria eriantha* subsp. *eriantha* (d), *Heteropogon contortus* (d), *Aristida congesta*, *A. diffusa*, *Enneapogon scoparius*, *Eragrostis rigidior*, *Tricholaena monachne*, *Triraphis andropogonoides*. Herb: *Vahlia capensis* subsp. *vulgaris*. Geophytic Herbs: *Boophone disticha*, *Drimia altissima*, *D. robusta*, *Eulophia petersii*. Succulent Herbs: *Aloe greatheadii* var. *greatheadii* (d), *Aeollanthus rehmannii*, *Avonia rhodesica*, *Crassula swaziensis*, *Plectranthus grandidentatus*, *P. hadiensis*.

Endemic Taxa Succulent Shrubs: *Euphorbia clivicola*, *Khadia media*.

Conservation Least threatened. Target 24%. Almost 8% statutorily conserved mainly in the Witvinger and Bewaarkloof Nature Reserves. About 6% transformed, including about 2% each of urban and built-up areas, plantations and cultivated land. Land uses include grazing, wood harvesting and medicinal plant collecting. Alien plants include *Nicotiana glauca*, *Opuntia* species and *Zinnia peruviana*. Erosion is generally moderate to very low, and high in some areas.

References Winter & Hahn (1999), Ndowana Exploration (Pty) Ltd (2003).

L. Mucina

Figure 9.32 SVcb 24 Mamabolo Mountain Bushveld: Granite koppie with abundant *Euphorbia cooperi* near Ga-Mankoeng, east of Polokwane.

SVcb 25 Poung Dolomite Mountain Bushveld

VT 19 Sourish Mixed Bushveld (44%), VT 8 North-Eastern Mountain Sourveld (43%) (Acocks 1953). LR 43 North-eastern Mountain Grassland (96%) (Low & Rebelo 1996).

Distribution Limpopo and Mpumalanga Provinces: Mountain slopes from the area of the Abel Erasmus Pass in the south, more or less continuously northwards along the western rainshadow side of the escarpment, including Poung

Mountain near Penge becoming discontinuous towards the Wolkberg and westwards along the Strydpoort Mountains to Chuniespoort and Mokopane. Altitude about 600–1 500 m extending to about 1 600 m in parts of the west.

Vegetation & Landscape Features Open to closed woodland with well-developed shrub layers. Low to high mountain slopes. Various slope angles, aspects and altitude, especially along the western extension.

Geology & Soils Geology almost entirely Malmani Formation dolomite of the Transvaal Supergroup with chert always interlayered. Soils with high pH, rich in calcium and magnesium, and with low levels of phosphorus. Soils are usually shallow (Mispah soil form) and occasionally deep (Hutton and Griffin soil forms). Land types mainly Ib and Fa.

Climate Summer rainfall with dry winters. MAP about 500–900 mm, lowest in the escarpment rainshadow and peaking near the border, with grassland at higher altitudes on the escarpment, lower on the Strydpoort Mountain part of this unit than on the escarpment. Mist absent and frost infrequent. See also climate diagram for SVcb 25 Poung Dolomite Mountain Bushveld.

Important Taxa Small Trees: *Hippobromus pauciflorus* (d), *Kirkia wilmsii* (d), *Seemannaralia gerrardii* (d), *Boscia albitrunca*, *Combretum hereroense, Croton gratissimus*, *Dombeya autumnalis*, *Vitex obovata* subsp. *wilmsii*. Succulent Tree: *Euphorbia tirucalli* (d). Tall Shrubs: *Pouzolzia mixta*, *Senna petersiana*. Low Shrubs: *Asparagus intricatus* (d), *Barleria rotundifolia*, *Euchaetis schlechteri*, *Rhynchosia nitens*. Geoxylic Suffrutex: *Ozoroa albicans*. Succulent Shrub: *Plectranthus xerophilus* (d). Woody Climbers: *Pristimera longipetiolata*, *Tecoma capensis*. Graminoids: *Bewsia biflora* (d), *Brachiaria serrata* (d), *Eragrostis lehmanniana* (d), *Loudetia simplex* (d), *Melinis repens* (d), *Panicum maximum* (d), *Themeda triandra* (d), *Enneapogon scoparius*, *Heteropogon contortus*, *Melinis nerviglumis*, *Panicum deustum*, *Tragus berteronianus*. Herb: *Stylochaeton natalensis*. Geophytic Herbs: *Cheilanthes dolomiticola* (d), *Sansevieria hyacinthoides*. Succulent Herb: *Plectranthus neochilus*.

Biogeographically Important Taxa ([N]Northern Sourveld endemic, [SK]Sekhukhune endemic) Small Tree: *Lydenburgia cassinoides*[SK] (d). Low Shrub: *Asparagus fourei*[N]. Soft Shrub: *Chorisochora transvaalensis*[N]. Megaherb: *Dracaena transvaalensis*[N] (d). Geophytic Herb: *Haemanthus pauculifolius*[N].

M.C. Lötter

Figure 9.33 SVcb 25 Poung Dolomite Mountain Bushveld: Rocky deciduous woodland, dominated by *Kirkia wilmsii* and *Combretum hereroense* with *Aloe fosteri*, *Sarcostemma viminale* and *Plectranthus xerophilus* northeast of Penge Mine, Limpopo Province.

Endemic Taxa Small Trees: *Encephalartos dolomiticus*, *E. inopinus*. Low Shrub: *Melhania integra*. Succulent Shrubs: *Delosperma vandermerwei*, *Euphorbia grandialata*. Herbs: *Barleria dolomiticola*, *Lotononis pariflora*. Geophytic Herbs: *Brachystelma minor*, *B. parvulum*, *Gladiolus dolomiticus*, *G. pavonia*, *Ledebouria dolomiticola*. Succulent Herbs: *Aloe branddraaiensis*, *A. monotropa*, *Gasteria batesiana* var. *dolomitica*, *Huernia blyderiverensis, Plectranthus dolomiticus*.

Conservation Least threatened. Target 24%. Some 10% statutorily conserved mainly in the Bewaarkloof and Lekgalameetse Nature Reserves. An additional 6% conserved in other reserves including the Wolkberg (Serala) Wilderness Area. About 6% transformed, mainly for cultivation. Erosion is very low to moderate.

Remark Species are often associated with the Wolkberg CE, although some species are also shared with the Sekhukhuneland CE (e.g. *Dombeya autumnalis*, *Orthosiphon tubiformis*) and other northern sourveld units.

References Stalmans (1990), Matthews (1991), Stalmans & De Klerk (1991, 1992), Van Wyk & Smith (2001).

SVcb 26 Ohrigstad Mountain Bushveld

VT 19 Sourish Mixed Bushveld (44%), VT 18 Mixed Bushveld (33%) (Acocks 1953). LR 43 North-eastern Mountain Grassland (52%) (Low & Rebelo 1996).

Distribution Limpopo and Mpumalanga Provinces: Mountain slopes and steep valleys from the Blyde River Canyon, Ohrigstad and Burgersfort in the south continuing in the vicinity of the western side of the escarpment northwards to the Mohlapitse Valley and eastwards along the Strydpoort Mountains as far as Chuniespoort. Altitude varies widely from around 500 m (in the Olifants River Gorge) to about 1 400 m.

Vegetation & Landscape Features Open to dense woody layer, with associated woody and herbaceous shrubs and closed to open grass layer. Moderate to steep slopes on mountainsides and sometimes deeply incised valleys; also fairly flat terrain in a few places.

Geology & Soils Primarily on quartzite and shale (Timeball Hill and Silverton Formations of the Pretoria Group), with some chemical sediments of the Chuniespoort Group, weathering to shallow rocky soils of either Glenrosa or Mispah soil forms. Land types mainly Ib, Ae and Fa.

Climate Summer rainfall with very dry winters. MAP about 500–800 mm. Frost infrequent. See also climate diagram for SVcb 26 Ohrigstad Mountain Bushveld.

Important Taxa Tall Tree: *Sclerocarya birrea* subsp. *caffra* (d). Small Trees: *Acacia exuvialis* (d), *A. karroo* (d), *A. tortilis* subsp. *heteracantha* (d), *Combretum apiculatum* (d), *C. molle* (d), *Kirkia wilmsii* (d), *Acacia caffra*, *Berchemia zeyheri*, *Boscia foetida* subsp. *rehmanniana*, *Commiphora mollis*, *Croton gratissimus*, *Englerophytum magalismontanum*, *Hippobromus pauciflorus*, *Pappea capensis*, *Terminalia prunioides*, *Vitex obovata* subsp. *wilmsii*, *Ziziphus mucronata*. Succulent Trees: *Euphorbia tirucalli* (d), *E. cooperi*. Tall Shrubs: *Dichrostachys*

W.L. McCleland

Figure 9.34 SVcb 26 Ohrigstad Mountain Bushveld: Moderately dense woodland on hillslopes with rocky substrate with common species including *Acacia caffra, Aloe marlothii, Elaeodendron transvaalense, Euclea crispa* (blue-leaved form) and *Englerophytum magalismontanum* near Crystal Springs Mountain Lodge, about 10 km from Ohrigstad.

cinerea (d), *Combretum petrophilum*, *Crotalaria monteiroi*, *Grewia bicolor*, *G. monticola*, *Hexalobus monopetalus*, *Karomia speciosa*, *Olea europaea* subsp. *africana*, *Tarchonanthus camphoratus*. Low Shrubs: *Grewia vernicosa* (d), *Psiadia punctulata* (d), *Euclea crispa*. Succulent Shrubs: *Aloe castanea* (d), *A. cryptopoda*, *A. globuligemma*. Woody Climber: *Pterolobium stellatum* (d). Graminoids: *Loudetia simplex* (d), *Andropogon chinensis*, *Aristida congesta*, *Brachiaria nigropedata*, *Eragrostis rigidior*, *Melinis repens*, *Panicum maximum*. Succulent Herb: *Aloe fosteri* (d).

Biogeographically Important Taxon (Central Bushveld endemic) Low Shrub: *Petalidium oblongifolium*.

Endemic Taxa Small Tree: *Encephalartos cupidus*. Woody Climbers: *Asparagus lynnetteae, Rhoicissus laetans*. Succulent Herbaceous Climber: *Ceropegia distincta* subsp. *verruculosa*.

Conservation Least threatened. Target 24%. Almost 8% statutorily conserved, mainly in the Bewaarkloof and Blyde River Canyon Nature Reserves. At least an additional 4% in other reserves, mainly the Wolkberg (Serala) Wilderness Area. At least 9% transformed, mostly by cultivation. Aliens include scattered *Melia azedarach*, *Caesalpinia decapetala* and *Nicotiana glauca*. Erosion is very variable, from very low to very high in parts of the Sekhukhune region.

Remarks Most of the unit is relatively dry mountain bushveld in the rainshadow west of the northern parts of the Drakensberg. The northern area of this unit has been included in the Wolkberg CE (Van Wyk & Smith 2001).

Reference Van Wyk & Smith (2001).

SVcb 27 Sekhukhune Plains Bushveld

VT 18 Mixed Bushveld (71%) (Acocks 1953). LR 18 Mixed Bushveld (97%) (Low & Rebelo 1996). *Acacia tortilis–Dichrostachys cinerea* Arid Northern Dry Bushveld (Siebert et al. 2002a).

Distribution Limpopo and Mpumalanga Provinces: Lowland area from Burgersfort and the lower basin of the Steelpoort River in the south, northwards through the plains of the Motse River basin to Jobskop and Legwareng (south of the Strydpoort Mountains). Continues up the basin of the Olifants River to around Tswaing and the valleys of the Lepellane and Mohlaletsi Rivers. Altitude mostly about 700–1 100 m.

Vegetation & Landscape Features Mainly semi-arid plains and open valleys between chains of hills and small mountains running parallel to the escarpment. Predominantly short, open to closed thornveld with an abundance of *Aloe* species and other succulents. Heavily degraded in places and overexploited by man for cultivation, mining and urbanisation. Both man-made and natural erosion dongas occur in areas containing clays rich in heavy metals. Encroachment by indigenous microphyllous trees and invasion by alien species is common throughout the area.

Geology & Soils Complex geology, with rocks mainly mafic and ultramafic intrusive rocks of the main to lower zones of the Rustenberg Layered Suite on the eastern lobe of the Bushveld Igneous Complex (Vaalian). The zones (subsuites) are dominated by concentric belts of norite, gabbro, anorthosite and pyroxenite, with localised protrusions of magnetite, chromatite, serpentinised harzburgite, olivine diorite, shale, dolomite and quartzite. Most of the area consists of red apedal soils. Deep, loamy Valsrivier soils are characteristic of the plains and shallow Glenrosa soils are found on the low-lying, rocky hills. Patches of erodable black, melanic structured horizons are common around small mountains. Some Steendal soils are underlain by gypsum. Land types mainly Ae, Ib, Ea and Ia.

Climate Summer rainfall with very dry winters. MAP about 400–600 mm, but at the lower end of this range on the central plains increasing to about 500 mm on the plains east of the Leolo Mountains. Frost very infrequent. Mean monthly maximum and minimum temperatures for Tswelopele 37.3°C and –0.9°C for January and June, respectively. Daily temperatures vary considerably at different localities, with higher temperatures on the western plains and lower temperatures on higher-lying plateaus. See also climate diagram for SVcb 27 Sekhukhune Plains Bushveld.

Important Taxa Tall Trees: *Acacia erioloba*, *Philenoptera violacea*. Small Trees: *Acacia mellifera* subsp. *detinens* (d), *A. nilotica* (d), *A. tortilis* subsp. *heteracantha* (d), *Boscia foetida* subsp. *rehmanniana* (d), *Acacia grandicornuta*, *Albizia anthelmintica*, *Balanites maughamii*, *Combretum imberbe*, *Commiphora glandulosa*, *Maerua angolensis*, *Markhamia zanzibarica*, *Mystroxylon aethiopicum* subsp. *schlechteri*, *Ptaeroxylon obliquum*, *Schotia brachypetala*, *Ziziphus mucronata*. Succulent Tree: *Euphorbia tirucalli* (d). Tall Shrubs: *Rhus engleri* (d), *Cadaba termitaria*, *Dichrostachys cinerea*, *Ehretia rigida* subsp. *rigida*, *Grewia bicolor*, *Karomia speciosa*, *Maerua decumbens*, *Rhigozum brevispinosum*, *R. obovatum*, *Tinnea rhodesiana*, *Triaspis glaucophylla*. Low Shrubs: *Felicia clavipilosa* subsp. *transvaalensis* (d), *Seddera suffruticosa* (d), *Gnidia polycephala*, *Gossypium herbaceum* subsp. *africanum*, *Jamesbrittenia atropurpurea*, *Jatropha latifolia* var. *latifolia*, *Lantana rugosa*, *Melhania rehmannii*, *Monechma divaricatum*, *Myrothamnus flabellifolius*, *Pechuel-Loeschea leubnitziae*, *Plinthus rehmannii*. Succulent Shrubs: *Aloe cryptopoda* (d), *Euphorbia enormis* (d), *Kleinia longiflora* (d), *Aloe castanea*, *A. globuligemma*. Woody Succulent

Climber: *Sarcostemma viminale*. Herbaceous Climbers: *Coccinia rehmannii*, *Decorsea schlechteri*. Graminoids: *Cenchrus ciliaris* (d), *Enneapogon cenchroides* (d), *Panicum maximum* (d), *Urochloa mosambicensis* (d), *Aristida adscensionis*, *A. congesta*, *Eragrostis barbinodis*, *Paspalum distichum*, *Schmidtia pappophoroides*, *Stipagrostis hirtigluma* subsp. *patula*, *Tragus berteronianus*. Herbs: *Becium filamentosum* (d), *Phyllanthus maderaspatensis* (d), *Blepharis integrifolia*, *Corchorus asplenifolius*, *Hibiscus praeteritus*, *Ipomoea magnusiana*. Geophytic Herbs: *Drimia altissima*, *Sansevieria pearsonii*.

Biogeographically Important Taxa ([N]Northern Sourveld endemic, [CB]Central Bushveld endemic, [SK]Sekhukhune endemic, [D]Broadly disjunct distribution) Small Tree: *Lydenburgia cassinoides*[SK]. Tall Shrub: *Nuxia gracilis*[D]. Low Shrubs: *Amphiglossa triflora*[D], *Asparagus fourei*[N], *Hibiscus barnardii*[SK], *Orthosiphon fruticosus*[CB], *Petalidium oblongifolium*[CB], *Rhus batophylla*[SK]. Woody Climber: *Asparagus sekukuniensis*[SK]. Herb: *Aneilema longirrhizum*[SK]. Geophytic Herb: *Chlorophytum cyperaceum*[SK]. Succulent Herb: *Piaranthus atrosanguineus*[CB].

Conservation Vulnerable. Target 19%. Nearly 2% statutorily conserved in Potlake, Bewaarkloof and Wolkberg Caves Nature Reserves. Approximately 25% of this area has been transformed and is mainly under dry-land subsistence cultivation. A small area is under pressure from chrome and platinum mining activities and the associated urbanisation. Depending on commodities, this threat could increase in the future. There is a high level of degradation of much of the remaining vegetation by unsustainable harvesting and utilisation. Erosion widespread at usually high to very high levels with donga formation. Alien *Agave* species, *Caesalpinia decapetala*, *Lantana camara*, *Melia azedarach*, *Nicotiana glauca*, *Opuntia* species, *Verbesina encelioides* and *Xanthium strumarium* are widespread but scattered.

Remarks This semi-arid bushveld is a disturbed and degraded system with many erosion dongas. However, much of the erosion can be attributed to inherent edaphic properties. The unit is situated in the Sekhukhuneland CE (Van Wyk & Smith 2001). Several endemic taxa of this unit still require formal description (Siebert et al. 2001). It is related to SVcb 28 Sekhukhune Mountain Bushveld, SVcb 23 Polokwane Plateau Bushveld and SVcb 15 Springbokvlakte Thornveld in terms of floristic diversity, species richness and vegetation structure (Breebaart & Deutschländer 1997, Siebert et al. 2002b).

References Breebaart & Deutschländer (1997), Siebert (2001), Siebert et al. (2001, 2002a, b, d, 2003a), Van Wyk & Smith (2001).

SVcb 28 Sekhukhune Mountain Bushveld

VT 19 Sourish Mixed Bushveld (50%) (Acocks 1953). LR 18 Mixed Bushveld (86%) (Low & Rebelo 1996). *Kirkia wilmsii–Terminalia prunioides* Closed Mountain Bushveld, *Combretum hereroense–Grewia vernicosa* Open Mountain Bushveld, *Hippobromus pauciflorus–Rhoicissus tridentata* Rock Outcrop Vegetation (Siebert et al. 2002a).

Distribution Limpopo and Mpumalanga Provinces: Mountains and undulating hills above the lowlands of the SVcb 27 Sekhukhune Plains Bushveld, including the steep slopes of the Leolo Mountains (except areas of Gm 20 Leolo Summit Sourveld), Dwars River Mountains (except areas of Gm 19 Sekhukhune Montane Grassland) and Thaba Sekhukhune, and a number of isolated smaller mountains (e.g. Phepane and Morone). Also the undulating small hills in the valley of the Steelpoort River up to and along the Klip River flowing past Roossenekal. Altitude about 900–1 600 m.

Vegetation & Landscape Features Dry, open to closed microphyllous and broad-leaved savanna on hills and mountain slopes that form concentric belts parallel to the northeastern escarpment. Open bushveld often associated with ultramafic soils on southern aspects. Bushveld on ultramafic soils contain a high diversity of edaphic specialists. Bushveld of mountain slopes generally taller than in the valleys, with a well-developed herb layer. Bushveld of valleys and dry northern aspects usually dense, like thicket, with a herb layer comprising many short-lived perennials. Dry habitats contain a number of species with xerophytic adaptations, such as succulence and underground storage organs. Both man-made and natural erosion dongas occur on footslopes of clays rich in heavy metals.

Geology & Soils Rocks mainly ultramafic intrusives of the lower, critical and main zones of the eastern Rustenberg Layered Suite of the Bushveld Igneous Complex (Vaalian). Three subsuites (zones), namely Croydon, Dwars River and Dsjate consist mainly of norite, pyroxenite, anorthosite and gabbro, and are characterised by localised intrusions of magnetite, diorite, dunite, bronzitite and harzburgite. Soils are predominantly shallow, rocky and clayey. Glenrosa and Mispah soil forms are common, with lime present in low-lying areas. Rocky areas without soil are common on steep slopes. The Dwars River Valley is characterised by prismacutanic horizons with melanic structured diagnostic horizons. Around Steelpoort red apedal, freely drained soils occur and these deeper soils include Hutton, Bonheim and Steendal soil forms. Land types mainly Ib, Ae, Ic and Fb.

Climate Summer rainfall with very dry winters. MAP about 500–700 mm, but local topography influences rainfall patterns over short distances. Frost fairly infrequent. Daily temperatures vary considerably at different localities, with highest temperatures in lower-lying areas and lowest temperatures on southern aspects of mountains. See also climate diagram for SVcb 28 Sekhukhune Mountain Bushveld.

Important Taxa Tall Tree: *Acacia nigrescens*. Small Trees: *Acacia senegal* var. *leiorhachis* (d), *Combretum apiculatum*

J.P.H. Acocks

Figure 9.35 SVcb 28 Sekhukhune Mountain Bushveld: Moderately open bushveld on upper slopes of the Leolo Mountains, Sekhukhune District, Limpopo Province.

(d), *Kirkia wilmsii* (d), *Terminalia prunioides* (d), *Vitex obovata* subsp. *wilmsii* (d), *Ziziphus mucronata* (d), *Bolusanthus speciosus*, *Boscia albitrunca*, *Brachylaena ilicifolia*, *Combretum molle*, *Commiphora mollis*, *Croton gratissimus*, *Cussonia transvaalensis*, *Hippobromus pauciflorus*, *Ozoroa sphaerocarpa*, *Pappea capensis*, *Schotia latifolia*, *Sterculia rogersii*. Succulent Tree: *Aloe marlothii* subsp. *marlothii*. Tall Shrubs: *Dichrostachys cinerea* (d), *Euclea crispa* subsp. *crispa* (d), *Combretum hereroense*, *Euclea linearis*, *Pavetta zeyheri*, *Tinnea rhodesiana*, *Triaspis glaucophylla*. Low Shrubs: *Elephantorrhiza praetermissa* (d), *Grewia vernicosa* (d), *Asparagus intricatus*, *Barleria saxatilis*, *B. senensis*, *Clerodendrum ternatum*, *Commiphora africana*, *Hermannia glanduligera*, *Indigofera lydenburgensis*, *Jatropha latifolia* var. *angustata*, *Melhania prostrata*, *Phyllanthus glaucophyllus*, *Psiadia punctulata*, *Rhus keetii*, *Rhynchosia komatiensis*. Succulent Shrubs: *Aloe castanea* (d), *A. cryptopoda* (d). Woody Climbers: *Clematis brachiata* (d), *Rhoicissus tridentata* (d), *Acacia ataxacantha*. Woody Succulent Climber: *Sarcostemma viminale*. Graminoids: *Aristida canescens* (d), *Heteropogon contortus* (d), *Panicum maximum* (d), *Setaria lindenbergiana* (d), *Themeda triandra* (d), *Aristida transvaalensis*, *Cymbopogon pospischilii*, *Diheteropogon amplectens*, *Enneapogon scoparius*, *Loudetia simplex*, *Panicum deustum*, *Setaria sphacelata*. Herbs: *Berkheya insignis* (d), *Commelina africana* (d), *Cyphostemma woodii*, *Kyphocarpa angustifolia*, *Senecio latifolius*. Geophytic Herbs: *Hypoxis rigidula*, *Sansevieria hyacinthoides*. Succulent Herb: *Huernia stapelioides*.

Biogeographically Important Taxa ([N]Northern Sourveld endemic, [CB]Central Bushveld endemic, [SK]Sekhukhune endemic, [Z]Link to Zimbabwe) Small Tree: *Lydenburgia cassinoides*[SK]. Tall Shrub: *Rhus sekhukhuniensis*[SK]. Low Shrubs: *Euclea sekhukhuniensis*[SK], *Petalidium oblongifolium*[CB], *Plectranthus venteri*[Z], *Rhus batophylla*[SK]. Woody Climbers: *Asparagus sekukuniensis*[SK], *Rhoicissus sekhukhuniensis*[SK]. Geophytic Herbs: *Chlorophytum cyperaceum*[SK], *Raphionacme chimanimaniana*[Z].

Endemic Taxa Small Tree: *Acacia ormocarpoides*. Succulent Tree: *Euphorbia sekukuniensis*. Soft Shrub: *Plectranthus porcatus*.

Conservation Least threatened. Target 24%. None conserved in statutory conservation areas, but 0.4% conserved in Potlake Nature Reserve. Nearly 15% transformed, mainly by cultivation and urban built-up. Erosion is at moderate to high levels, with donga formation in places. An increasing area along the Dwars River Subsuite is under pressure from mining activities and its associated urbanisation (Siebert et al. 2002d). *Melia azedarach* is currently the most aggressive alien invader.

Remarks This mountain bushveld is part of the Sekhukhuneland CE (Van Wyk & Smith 2001), more specifically the Steelpoort Subcentre. This vegetation unit is not heavily disturbed or degraded and its vast range of habitat still harbours high plant diversity with many endemics, many of which still await formal description (Siebert et al. 2001). It is related to SVcb 27 Sekhukhune Plains Bushveld, SVcb 7 Norite Koppies Bushveld and SVcb 26 Ohrigstad Mountain Bushveld in terms of floristic diversity, species richness and vegetation structure (Siebert et al. 2002b, c).

References Siebert (2001), Siebert et al. (2001, 2002a, b, c, d, 2003b), Van Wyk & Smith (2001).

Mopane

SVmp 1 Musina Mopane Bushveld

VT 15 Mopani Veld (80%) (Acocks 1953). LR 10 Mopane Bushveld (69%) (Low & Rebelo 1996).

Distribution Limpopo Province: Undulating plains from around Baines Drift and Alldays in the west, remaining north of the Soutpansberg and south of the Limpopo River (but also occurring to the north in Zimbabwe), through Musina and Tshipise to Malongavlakte, Masisi and Banyini Pan in the east. Altitude about 300 m (in the eastern Limpopo Valley) to 800 m.

Vegetation & Landscape Features Undulating to very irregular plains, with some hills. In the western section, open woodland to moderately closed shrubveld dominated by *Colophospermum mopane* on clayey bottomlands and *Combretum apiculatum* on hills. In the eastern section on basalt, moderately closed to

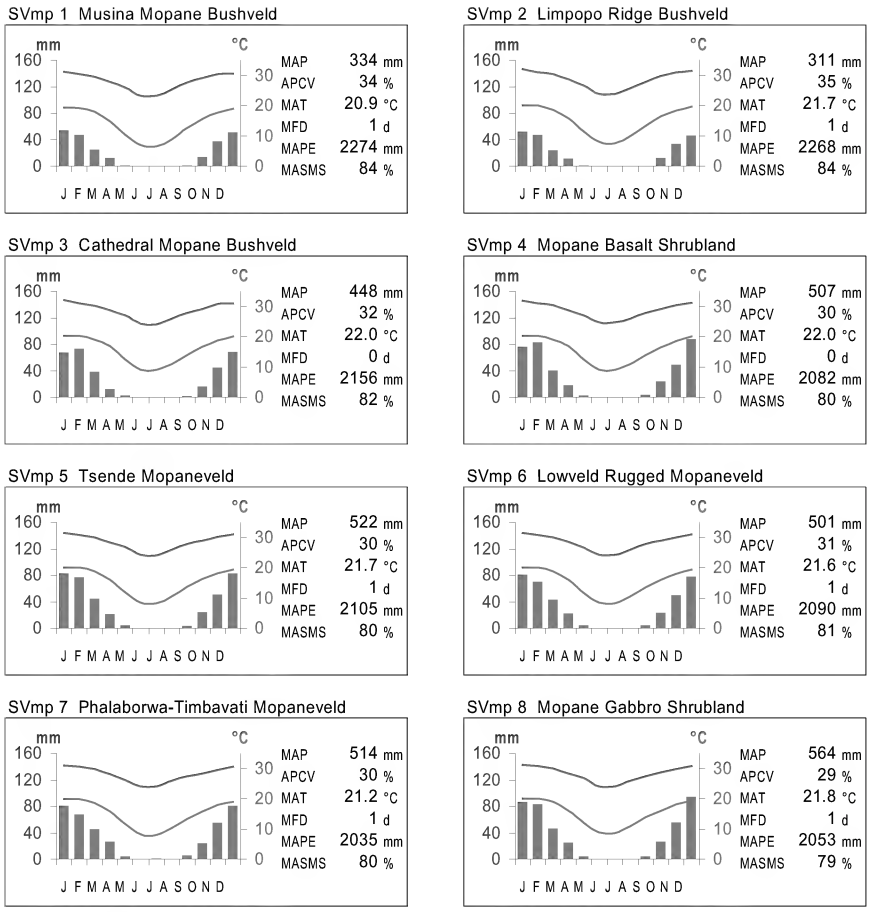
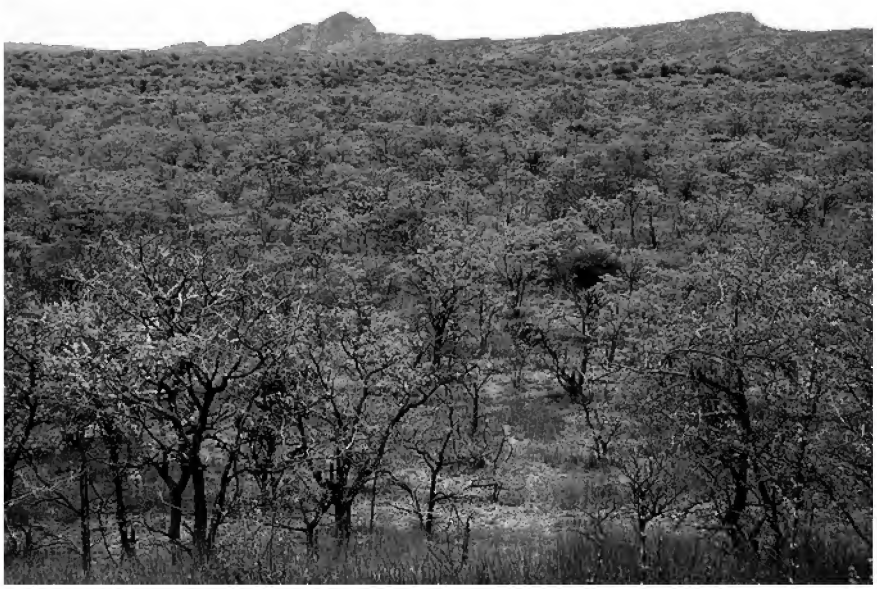


Figure 9.36 Climate diagrams of Mopane Bioregion units. Blue bars show the median monthly precipitation. The upper and lower red lines show the mean daily maximum and minimum temperature respectively. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days (days when screen temperature was below 0°C); MAPE: Mean Annual Potential Evaporation; MASMS: Mean Annual Soil Moisture Stress (% of days when evaporative demand was more than double the soil moisture supply).



L. Mucina

Figure 9.37 SVmp 1 Musina Mopane Bushveld: Bushveld dominated by *Colophospermum mopane* in the Honnet Nature Reserve near Tshipise (Musina District, Limpopo Province).

open shrubveld is dominated by *Colophospermum mopane* and *Terminalia prunioides*. On areas with deep sandy soils, moderately open savanna dominated by *Colophospermum mopane*, *T. sericea*, *Grewia flava* and *Combretum apiculatum*. Field layer well developed (especially on the basalt), open during the dry season; the herbaceous layer is poorly developed in areas with dense cover of *Colophospermum mopane* shrubs, for example, north of Alldays bordering the Limpopo floodplain.

Geology & Soils Most of the area is underlain by the Archaean Beit Bridge Complex, except where it is covered by much younger Karoo sandstones and basalts. The Beit Bridge Complex consists of gneisses and metasediments and is structurally very complex. Variable soils from deep red/brown clays, moderately deep, dark, heavy clays to deep, freely drained sandy soils to shallower types including skeletal Glenrosa and Mispah soil forms. Land types mainly Ae, Ah, Fc and Db.

Climate Summer rainfall with very dry winters including the shoulder months of May and September. MAP about 300–400 mm. Generally frost-free unit. Mean monthly maximum and minimum temperatures for Macuville-Agr (northwest of Musina) 39.9°C and 0.9°C for November and June, respectively. See also climate diagram for SVmp 1 Musina Mopane Bushveld.

Important Taxa Tall Trees: *Acacia nigrescens*, *Adansonia digitata*, *Sclerocarya birrea* subsp. *caffra*. Small Trees: *Colophospermum mopane* (d), *Combretum apiculatum* (d), *Acacia senegal* var. *leiorhachis*, *A. tortilis* subsp. *heteracantha*, *Boscia albitrunca*, *B. foetida* subsp. *rehmanniana*, *Commiphora glandulosa*, *C. tenuipetiolata*, *C. viminea*, *Sterculia rogersii*, *Terminalia prunioides*, *T. sericea*, *Ximenia americana*. Tall Shrubs: *Grewia flava* (d), *Sesamothamnus lugardii* (d), *Commiphora pyracanthoides*, *Gardenia volkensii*, *Grewia bicolor*, *Maerua parvifolia*, *Rhigozum zambesiacum*, *Tephrosia polystachya*. Low Shrubs: *Acalypha indica*, *Aptosimum lineare*, *Barleria senensis*, *Dicoma tomentosa*, *Felicia clavipilosa* subsp. *transvaalensis*, *Gossypium herbaceum* subsp. *africanum*, *Hermannia glanduligera*, *Neuracanthus africanus*, *Pechuel-Loeschea leubnitziae*, *Ptycholobium contortum*, *Seddera suffruticosa*. Succulent Shrub: *Hoodia currorii* subsp. *lugardii*. Herbaceous Climber: *Momordica balsamina*. Graminoids: *Schmidtia pappophoroides* (d), *Aristida adscensionis*, *A. congesta*, *Bothriochloa insculpta*, *Brachiaria deflexa*, *Cenchrus ciliaris*, *Digitaria eriantha* subsp. *eriantha*, *Enneapogon cenchroides*, *Eragrostis lehmanniana*, *E. pallens*, *Fingerhuthia africana*, *Heteropogon contortus*, *Sporobolus nitens*, *Stipagrostis hirtigluma* subsp. *patula*, *S. uniplumis*, *Tetrapogon tenellus*, *Urochloa mosambicensis*. Herbs: *Acrotome inflata*, *Becium filamentosum*, *Harpagophytum procumbens* subsp. *transvaalense*, *Heliotropium steudneri*, *Hermbstaedtia odorata*, *Oxygonum delagoense*. Succulent Herbs: *Stapelia gettliffei, S. kwebensis.*

Conservation Least threatened. Target 19%. Only 2% statutorily conserved mainly in the Mapungubwe National Park as well as in Nwanedi and Honnet Nature Reserves. Additionally, about 1% conserved in the Baobab Tree Reserve. Roughly 3% transformed, mainly by cultivation. Erosion is high to moderate.

Remarks The unit is the most diverse mopaneveld type in South Africa. The Musina region has the highest species richness—also relative to *Colophospermum mopane*-dominated areas in Namibia and the Save River Valley in Zimbabwe (F. Siebert et al. 2003). The relationship of this unit with the adjacent and often fragmented parts of SVmp 2 Limpopo Ridge Bushveld is spatially complex. It is very dependent on scale and has not been fully captured on the map.

References Louw (1970), O'Connor (1992), Dekker & Van Rooyen (1995), Visser et al. (1996), Du Plessis (2001), Götze (2002), Straub (2002), Jordaan et al. (2004).

SVmp 2 Limpopo Ridge Bushveld

VT 15 Mopani Veld (82%) (Acocks 1953). LR 10 Mopane Bushveld (81%) (Low & Rebelo 1996).

Distribution Limpopo Province: On hills and ridges, such as Madiapala in the lower Mogalakwena River basin in the west through a cluster of hills in the Pontdrif area including Poortjieberg and Tsolwe, eastwards including Mapungubwe Mountain in the Mapungubwe National Park through to the hills and ridges in the vicinity of the Limpopo River further downstream (for example Ha-Tshansi at Musina, Ha-Dowe and Maremani). Also including hills and ridges well away from the river north of the Soutpansberg and generally east of the Sand River (e.g. Tshitangai, Bloukop and Ha-Manenzhe) through to some rugged areas in the far northern Kruger National Park. Altitude from about 300 m in the east to 700 m, with the top of a few hills in the west at around 1 000 m.

Vegetation & Landscape Features Extremely irregular plains with ridges and hills. Moderately open savanna with poorly developed ground layer. Umbrella-shape canopied *Kirkia acuminata* is prominent on some ridge skylines with the often enormous *Adansonia digitata* on shallow calcareous gravel; the shrub *Catophractes alexandri* is dominant on calc-silicate soils. These are particularly striking landscapes with rock walls and passages within areas of sandstone of the Clarens Formation (e.g. within the Mapungubwe National Park).

Geology & Soils Mostly rocks of the Beit Bridge Complex (Swazian Erathem) as well as sediments (including sandstones of the Clarens Formation) and basalt (particularly in the east) of

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Figure 9.38 SVmp 2 Limpopo Ridge Bushveld: *Kirkia acuminata* trees on a rocky hillside at 560 m on Leokwe Hill in Mapungubwe National Park.

SVmp 3 Cathedral Mopane Bushveld

VT 15 Mopani Veld (59%) (Acocks 1953). LR 10 Mopane Bushveld (80%) (Low & Rebelo 1996). KNP 15 *Colophospermum mopane* Forest (99%) (Gertenbach 1983b).

Distribution Limpopo Province: Mapped as a limited area in the Kruger National Park on the flats east of Punda Maria Gate from around Dzundwini Mountain to Gumbandebvu Hills. Also extends northwards in the upper Madzaringwe River Valley and in the Shilahlandonga River Valley to the east. Altitude 350–500 m.

Vegetation & Landscape Features A high, moderately closed tree savanna overwhelmingly dominated by *Colophospermum mopane* 10–15 m tall, often with some shrubs (e.g. *Euclea divinorum*) 2–3 m tall in the understorey, and a sparse herbaceous layer. The upper canopy is seldom closed. Vegetation of this unit occurs on flats and gentle slopes.

Geology & Soils Sandstone and shale of the Karoo Supergroup are most important, with sandstone, basalt and tuff of the Karoo Supergroup. Shallow gravel and sand (Glenrosa and Mispah soil forms) to calcareous clayey soil. Land types mainly Fc, Fb and Ib.

Climate Summer rainfall with very dry winters including the shoulder months of May and September. MAP about 300–400 mm. Generally a frost-free area. See also climate diagram for SVmp 2 Limpopo Ridge Bushveld.

Important Taxa Tall Trees: *Adansonia digitata* (d), *Acacia nigrescens*, *Sclerocarya birrea* subsp. *caffra*. Small Trees: *Colophospermum mopane* (d), *Commiphora glandulosa* (d), *C. tenuipetiolata* (d), *Terminalia prunioides* (d), *Acacia senegal* var. *leiorhachis*, *A. tortilis* subsp. *heteracantha*, *Boscia albitrunca*, *Combretum apiculatum*, *C. imberbe*, *Commiphora mollis*, *Ficus abutilifolia*, *F. tettensis*, *Kirkia acuminata*, *Sterculia rogersii*, *Ximenia americana*. Tall Shrubs: *Catophractes alexandri*, *Commiphora pyracanthoides*, *Gardenia resiniflua*, *Grewia bicolor*, *G. villosa*, *Hibiscus calyphyllus*, *H. micranthus*. Low Shrubs: *Barleria affinis*, *Blepharis diversispina*, *Neuracanthus africanus*, *Plinthus rehmannii*, *Ptycholobium contortum*. Woody Climber: *Cissus cornifolia*. Graminoids: *Aristida adscensionis*, *A. stipitata* subsp. *graciliflora*, *Digitaria eriantha* subsp. *eriantha*, *Enneapogon cenchroides*, *Panicum maximum*, *Schmidtia pappophoroides*, *Stipagrostis uniplumis*. Succulent Herb: *Tavaresia barklyi*.

Endemic Taxa Low Shrub: *Pavonia dentata*. Herb: *Cleome oxyphylla* var. *robusta*.

Conservation Least threatened. Target 19%. Some 18% statutorily conserved, mainly in the Kruger and Mapungubwe National Parks. An additional 2% conserved in the Baobab Tree Reserve (thus together attaining the target). Only about 1% is transformed, mainly for cultivation and mining.

Remark The correspondence of this vegetation unit with the landscape units of Gertenbach (1983b) and of others below that occur within the Kruger National Park, is given in Table 9.1.

References Louw (1970), Van Rooyen (1978), Gertenbach (1983b), O'Connor (1992), Dekker & Van Rooyen (1995), Visser et al. (1996), Du Plessis (2001), Götze (2002), Straub (2002), Jordaan et al. (2004).

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Figure 9.39 SVmp 3 Cathedral Mopane Bushveld : Tall *Colophospermum* mopane trees outside the mapped unit and associated with the drainage area of the Kolope River in Mapungubwe National Park.

Table 9.1 Correspondence within the Kruger National Park between vegetation types and landscapes (Gertenbach 1983b), with landscapes in decreasing order of area within a vegetation type.

Vegetation Units	Landscapes
SVmp 2 Limpopo Ridge Bushveld	KNP 25 *Adansonia digitata* / *Colophospermum mopane* Rugged Veld
	KNP 26 *Colophospermum mopane* Shrubveld on Calcrete
SVmp 3 Cathedral Mopane Bushveld	KNP 15 *Colophospermum mopane* Forest
SVmp 4 Mopane Basalt Shrubland	KNP 23 *Colophospermum mopane* Shrubveld on Basalt
	KNP 22 *Combretum* / *Colophospermum mopane* Rugged Veld
SVmp 5 Tsende Mopaneveld	KNP 11 Tsende Sandveld
	KNP 12 *Colophospermum mopane* / *Acacia nigrescens* Savanna
	KNP 9 *Colophospermum mopane* Woodland / Savanna on Basic Soils
	KNP 27 Mixed *Combretum* / *Colophospermum mopane* Woodland
SVmp 6 Lowveld Rugged Mopaneveld	KNP 10 Letaba River Rugged Veld
	KNP 7 Olifants River Rugged Veld
SVmp 7 Phalaborwa-Timbavati Mopaneveld	KNP 6 *Combretum* / *Colophospermum mopane* Woodland of Timbavati-area
	KNP 8 Phalaborwa Sandveld
SVmp 8 Mopane Gabbro Shrubland	KNP 24 *Colophospermum mopane* Shrubveld on Gabbro
SVl 1 Makuleke Sandy Bushveld	KNP 34 Punda Maria Sandveld on Waterberg Sandstone
	KNP 16 Punda Maria Sandveld on Cave Sandstone
	KNP 33 *Pterocarpus rotundifolius* / *Combretum collinum* Woodland
SVl 2 Nwambyia-Pumbe Sandy Bushveld	KNP 32 Nwambia Sandveld
	KNP 30 Pumbe Sandveld
SVl 3 Granite Lowveld	KNP 5 Mixed *Combretum* / *Terminalia sericea* Woodland
	KNP 4 Thickets of the Sabie & Crocodile River
	KNP 3 *Combretum collinum* / *Combretum zeyheri* Woodland
SVl 4 Delagoa Lowveld	KNP 13 *Acacia welwitschii* Thickets on Karoo Sediments
SVl 5 Tshokwane-Hlane Basalt Lowveld	KNP 17 *Sclerocarya birrea* subsp. *caffra* /*Acacia nigrescens* Savanna
	KNP 18 Dwarf *Acacia nigrescens* Savanna
	KNP 21 *Combretum* / *Acacia nigrescens* Rugged Veld
	KNP 20 Bangu Rugged Veld
	KNP 14 Kumana Sandveld
SVl 6 Gabbro Grassy Bushveld	KNP 19 Thornveld on Gabbro
SVl 10 Pretoriuskop Sour Bushveld	KNP 1 Lowveld Sour Bushveld of Pretoriuskop
SVl 11 Malelane Mountain Bushveld	KNP 2 Malelane Mountain Bushveld
SVl 15 Northern Lebombo Bushveld	KNP 29 Lebombo South
	KNP 31 Lebombo North

Soutpansberg Group (Mokolian Erathem) also significant. Soils are often deep, with high sodium content. Prismacutanic and/or pedocutanic diagnostic horizons are often dominant. Land types mainly Dc, Fc and Ca.

Climate Summer rainfall with very dry winters. MAP about 400–500 mm. Generally a frost-free area. See also climate diagram for SVmp 3 Cathedral Mopane Bushveld.

Important Taxa Tall Trees: *Colophospermum mopane* (d), *Acacia nigrescens*. Small Trees: *Combretum imberbe*, *Spirostachys africana*, *Ximenia americana*. Tall Shrubs: *Euclea divinorum* (d), *Combretum hereroense*, *Grewia bicolor*, *Hibiscus micranthus*, *Maerua parvifolia*. Low Shrub: *Neuracanthus africanus*. Graminoids: *Enneapogon cenchroides* (d), *Enteropogon macrostachyus* (d), *Aristida congesta*, *Panicum maximum*, *Schmidtia pappophoroides*. Herbs: *Amaranthus thunbergii*, *Seddera capensis*.

Conservation Least threatened. Target 19%. Entirely statutorily conserved in the Kruger National Park. Erosion is low to moderate.

Remarks Forms of this structural type occur unmapped in a number of small areas north of the Soutpansberg, usually forming bands along less major water courses, allied to that on some alluvial soils close to larger streams and rivers (e.g. stretches of the Tsende River north of the Letaba River). The unit is related to the SVl 4 Delagoa Lowveld in moister areas further south.

References Van Rooyen (1978), Van Rooyen et al. (1981b), Gertenbach (1983b).

SVmp 4 Mopane Basalt Shrubland

VT 15 Mopani Veld (90%) (Acocks 1953). LR 9 Mopane Shrubveld (74%) (Low & Rebelo 1996). KNP 23 *Colophospermum mopane* shrubveld on basalt (71%) (Gertenbach 1983b).

Distribution Limpopo and Mpumalanga Provinces: Mainly occurs in a large belt on the plains in the Kruger National Park from around Klopperfontein in the north, southwards and east of the Lebombo Mountain range through the Shingwedzi and Letaba Rest Camp areas to the vicinity of Olifants and Roodewal Rest Camps in the south. Altitude about 200–450 m.

Vegetation & Landscape Features Mainly plains and slightly undulating plains with medium-low (1–2 m) shrubs dominated overwhelmingly by multistemmed *Colophospermum mopane*. Tree forms of mopane are rare. Grass layer is well developed. Vegetation consists of three main variations depending on topographical position (Gertenbach 1983b): (1) lower, middle and footslopes, (2) middle slopes and convex uplands on usually deeper soils, and (3) concave terrain with soils with very high clay content. The unit includes some bottomlands and parts of the Lebombo pediment with a slightly increased proportion of other woody plant species.

Geology & Soils The area is built almost entirely by basalts (tholeitic and picritic) of the Letaba Formation (Lebombo Group, Karoo Supergroup). Soils are often deep and have a high clay content with a dark colour in the lower positions, becoming red on the higher middle slopes. Land types mainly Ea, with some Ia and Fb.

Climate Summer rainfall with very dry winters. MAP about 400–600 mm. Generally a frost-free area. Mean monthly maximum and minimum temperatures for Shingwedzi 40.8°C and 2.4°C for November and June, respectively. See also climate diagram for SVmp 4 Mopane Basalt Shrubland.

Important Taxa Tall Trees: *Acacia nigrescens*, *Philenoptera violacea*, *Sclerocarya birrea* subsp. *caffra*. Small Trees: *Acacia exuvialis*, *A. tortilis* subsp. *heteracantha*, *Combretum apiculatum*, *C. imberbe*, *Commiphora glandulosa*, *C. mollis*, *Dalbergia melanoxylon*, *Kirkia acuminata*, *Terminalia phanerophlebia*, *T. prunioides*. Tall Shrubs: *Colophospermum mopane* (d), *Combretum hereroense*, *Flueggea virosa*, *Grewia bicolor*, *Hibiscus calyphyllus*, *H. micranthus*, *Maerua parvifolia*, *Tephrosia polystachya*. Low Shrubs: *Clerodendrum ternatum*, *Dicoma tomentosa*, *Neuracanthus africanus*. Woody Climber: *Combretum mossambicense*. Herbaceous Climber: *Rhynchosia totta*. Graminoids: *Aristida congesta*, *Bothriochloa radicans*, *Cenchrus ciliaris*, *Enneapogon cenchroides*, *Fingerhuthia africana*, *Heteropogon contortus*, *Panicum maximum*, *Schmidtia pappophoroides*, *Setaria incrassata*, *Themeda triandra*, *Urochloa mosambicensis*. Herbs: *Heliotropium steudneri*, *Leucas glabrata*, *Phyllanthus asperulatus*. Geophytic Herb: *Sansevieria hyacinthoides*.

Conservation Least threatened. Target 19%, but 100% already statutorily conserved in the Kruger National Park.

Remark The contrast along the interface between the low mopane shrubs of this unit and the very tall mopane trees of the neighbouring SVmp 3 Cathedral Mopane Bushveld is striking.

References Van Rooyen (1978), Gertenbach & Potgieter (1979), Van Rooyen et al. (1981b), Gertenbach (1983a, b), Fraser et al. (1987).

SVmp 5 Tsende Mopaneveld

VT 15 Mopani Veld (77%) (Acocks 1953). LR 10 Mopane Bushveld (92%) (Low & Rebelo 1996).

Distribution Limpopo Province: The main block occurs on undulating terrain west of the basalt plains from the Mphongolo River and Sirheni Bushveld Camp area in the north, southwards across the Shingwedzi River and extending slightly outside the Kruger National Park to include areas near to Malamulele and Mahlathi, through the upper Tsende River catchment area to around Mopani Camp in the south. Another belt occurs further south from the area around the Hans Merensky Nature Reserve in the west to the vicinity of Letaba Rest Camp in the east. It is also mapped as a narrow irregular strip immediately to the east of the basalt plains as far south as the Shingwedzi River area. Altitude about 300–550 m.

Vegetation & Landscape Features Slightly undulating plains with medium-high shrubby savanna, with some trees and dense ground layer dominated by *Colophospermum mopane*, but with the ratio of *C. mopane* to *Combretum apiculatum* decreasing somewhat on the less clayey soils of the uplands. In the northwestern parts the tree cover is greater and, together with the southern and northeastern outliers of the unit, these flatter landscapes include several trees such as *Acacia nigrescens* in addition to the dominant *Colophospermum mopane*.

H.C. Eckhardt

Figure 9.40 SVmp 4 Mopane Basalt Shrubland: Open shrubland dominated by *Colophospermum mopane*, approximately 14 km northeast of Mopani Rest Camp, Kruger National Park.

Geology & Soils Three quarters of the area is underlain by potassium-poor, quartz-feldspar rocks of the Goudplaats Gneiss Basement. The northeastern part of the area lies on Letaba basalts of the Karoo Supergroup. Typically clayey soils occur, but with less than 15% clay in the A-horizon on the upland positions. Generally deeper clayey soils are found on the flats; the northeastern outlier area has more sandy soils—weathered products of basalt and Quaternary sand and gravel.

Climate Summer rainfall with very dry winters. MAP about 450–650 mm. Generally a frost-free area. See also climate diagram for SVmp 5 Tsende Mopaneveld.

M.C. Rutherford

Figure 9.41 SVmp 5 Tsende Mopaneveld: Aerial view of the Tsende Mopaneveld on the right in strong contrast to the far less wooded Mopane Basalt Shrubland on the left. North of Mopani Rest Camp, Kruger National Park.

Important Taxa Tall Trees: *Acacia nigrescens*, *Sclerocarya birrea* subsp. *caffra*. Small Trees: *Colophospermum mopane* (d), *Combretum apiculatum* (d), *Acacia gerrardii*, *A. tortilis* subsp. *heteracantha*, *Albizia harveyi*, *Bridelia mollis*, *Cassia abbreviata* subsp. *beareana*, *Combretum imberbe*, *C. zeyheri*, *Dalbergia melanoxylon*, *Peltophorum africanum*, *Philenoptera violacea*, *Terminalia sericea*. Tall Shrubs: *Combretum hereroense*, *Dichrostachys cinerea*, *Euclea divinorum*, *Grewia bicolor*, *G. monticola*, *Strychnos madagascariensis*, *Tephrosia polystachya*. Low Shrubs: *Clerodendrum ternatum*, *Indigofera schimperi*, *Melhania forbesii*. Woody Climbers: *Cissus cornifolia*, *Combretum mossambicense*. Graminoids: *Bothriochloa radicans* (d), *Digitaria eriantha* subsp. *pentzii* (d), *Heteropogon contortus* (d), *Panicum maximum* (d), *Themeda triandra* (d), *Cymbopogon pospischilii*, *Enneapogon cenchroides*, *Eragrostis rigidior*, *E. superba*, *Panicum coloratum*, *Perotis patens*, *Pogonarthria squarrosa*, *Schmidtia pappophoroides*, *Urochloa mosambicensis*. Herbs: *Blepharis integrifolia*, *Ceratotheca triloba*, *Chamaecrista absus*, *Corchorus asplenifolius*, *Evolvulus alsinoides*, *Heliotropium steudneri*.

Conservation Least threatened. Target 19%. Some 63% statutorily conserved, almost all in the Kruger National Park, with some patches in the Hans Merensky Nature Reserve. About a further 5% is conserved in private reserves, mainly in the Groot-Letaba Wildreservaat. Some 12% of the area has been transformed, mainly through cultivation and some settlement development outside the Kruger National Park.

Remark In most of the main (northern) block of this unit, pans are very common (Gertenbach 1983b).

References Gertenbach (1983a, b), Fraser et al. (1987).

SVmp 6 Lowveld Rugged Mopaneveld

VT 11 Arid Lowveld (55%) (Acocks 1953). LR 10 Mopane Bushveld (87%) (Low & Rebelo 1996).

Distribution Limpopo and Mpumalanga Provinces: Broken veld from the area southeast of Giyani in the west to Shimuwini and Boulders Camps in the east as well as the rugged area of the Olifants River Valley south of Phalaborwa, from Grietjieberg in the west to the Maveni River tributary in the east. Altitude 250–550 m.

Vegetation & Landscape Features Slightly to extremely irregular plains with sometimes steep slopes and a number of prominent hills. The area around the Olifants River has more dissected and steeper slopes than the northern part of this unit. Usually dense shrubs with occasional trees and a sparse ground layer. Woody plants can become particularly dense where fire is excluded by very rocky terrain, such as in the vicinity of the Olifants River. Vegetation is more open in the northeastern parts of this unit outside the Kruger National Park.

Geology & Soils The Goudplaats Gneiss and Makhutswi Gneiss underlie most of this area, with a smaller contribution from the ultramafic metavolcanics (rocks rich in chlorite, amphibole, talc and serpentine) and metasediments of the Giyani Greenstone Belt (all Swazian Erathem). Soils are red-yellow apedal, freely drained, but also shallow and stony, especially in the east. Soil forms are mainly Hutton, Mispah and Glenrosa. Land types Ae, Fb and Fa.

Climate Summer rainfall with very dry winters. MAP about 400–600 mm. Generally a frost-free area, but frost sometimes occurs in the low-lying areas. See also climate diagram for SVmp 6 Lowveld Rugged Mopaneveld.

Important Taxa Tall Trees: *Acacia nigrescens*, *Sclerocarya birrea* subsp. *caffra*. Small Trees: *Colophospermum mopane* (d), *Combretum apiculatum* (d), *Terminalia prunioides* (d), *Acacia exuvialis*, *A. nilotica*, *Boscia albitrunca*, *Commiphora mollis*, *Dalbergia melanoxylon*. Tall Shrubs: *Combretum hereroense*, *Dichrostachys cinerea*, *Grewia bicolor*, *G. villosa*, *Rhigozum zambesiacum*. Low Shrubs: *Commiphora africana*, *Melhania forbesii*, *M. rehmannii*, *Solanum panduriforme*. Graminoids: *Aristida congesta* (d), *Enneapogon cenchroides* (d), *Melinis repens* (d), *Sporobolus panicoides* (d), *Bothriochloa radicans*, *Digitaria eriantha* subsp. *pentzii*, *Fingerhuthia africana*, *Panicum maximum*. Herbs: *Crabbea velutina*, *Heliotropium steudneri*, *Hemizygia elliottii*, *Hibiscus sidiformis*, *Phyllanthus asperulatus*, *Xerophyta retinervis*.

Conservation Least threatened. Target 19%. Some 34% statutorily conserved, almost all in the Kruger National Park. At least an additional 5% conserved in private reserves, such as Klaserie, Letaba Ranch and Selati Game Reserve. About 20% already transformed mainly by cultivation and some urban and built-up areas. This vegetation occurring outside the conserved areas is under pressure from high-density rural human population and associated urban sprawl and agricultural activities. Some areas experience moderate erosion.

Remark The southern part of this unit in the Kruger National Park contains a number of tree species that are relatively

scarce elsewhere in the park, e.g. *Kirkia wilmsii* and *Hexalobus monopetalus*.

References Gertenbach (1983a, b).

SVmp 7 Phalaborwa-Timbavati Mopaneveld

VT 11 Arid Lowveld (68%) (Acocks 1953). LR 10 Mopane Bushveld (77%) (Low & Rebelo 1996).

Distribution Limpopo and Mpumalanga Provinces: Occurs in a band about 40 km west and east of Phalaborwa and also occurs south of the Olifants River on the boundary between the Timbavati Game Reserve and the Kruger National Park including parts of the Umbabat and Klaserie Nature Reserves. Altitude 300–600 m.

Vegetation & Landscape Features Open tree savanna on undulating plains with the sandy uplands dominated by *Combretum apiculatum*, *Terminalia sericea* and *Colophospermum mopane* trees, with *T. sericea* disappearing and *Combretum apiculatum* becoming less common in the clayey bottomlands, and being replaced by trees such as *Acacia nigrescens* and increased dominance of *Colophospermum mopane*. The field layer is usually well developed. A feature of the northern section of this unit is the large number of termite mounds on the uplands.

Geology & Soils Quartz-feldspar rocks of the Makhutswi Gneiss (Swazian) dominate this area, except in the northwest where they are intruded by the Lekkersmaak Granite (Randian). Sandy soils (usually less than 10% clay in the A-horizon) on the uplands (e.g. Clovelly soil form) and clay soils in the bottomlands (e.g. Valsrivier and Sterkspruit soil forms). The dominant land type mapped is mainly Fb.

Climate Summer rainfall with very dry winters. MAP about 400–600 mm. Generally frost-free. Mean monthly maximum and minimum temperatures for Phalaborwa 38.4°C and 5.7°C for January and July, respectively. See also climate diagram for SVmp 7 Phalaborwa-Timbavati Mopaneveld.

Important Taxa Tall Trees: *Acacia nigrescens*, *Sclerocarya birrea* subsp. *caffra*. Small Trees: *Colophospermum mopane* (d), *Combretum apiculatum* (d), *Terminalia sericea* (d), *Acacia exuvialis*, *A. tortilis* subsp. *heteracantha*, *Albizia harveyi*, *Cassia abbreviata* subsp. *beareana*, *Combretum zeyheri*, *Dalbergia melanoxylon*, *Ozoroa engleri*, *Peltophorum africanum*, *Pseudolachnostylis maprouneifolia*. Tall Shrubs: *Combretum hereroense*, *Euclea divinorum*, *Grewia bicolor*, *Maerua parvifolia*, *Strychnos madagascariensis*, *Tephrosia polystachya*. Low Shrubs: *Clerodendrum ternatum*, *Commiphora africana*, *Hermannia glanduligera*, *Melhania forbesii*. Woody Climber: *Cissus cornifolia*. Graminoids: *Digitaria eriantha* subsp. *pentzii* (d), *Eragrostis rigidior* (d), *Pogonarthria squarrosa* (d), *Andropogon gayanus*, *Aristida congesta*, *Brachiaria nigropedata*, *Melinis repens*, *Panicum maximum*, *Perotis patens*, *Schmidtia pappophoroides*, *Themeda triandra*. Herbs: *Evolvulus alsinoides*, *Heliotropium steudneri*, *Hemizygia elliottii*, *Ipomoea magnusiana*, *Kohautia virgata*.

Conservation Least threatened. Target 19%. Some 38% statutorily conserved in the Kruger National Park, with a similar proportion in the private Selati Game Reserve and Umbabat, Timbavati, Klaserie Nature Reserves. About 5% has been transformed, mainly by development of human settlements as well as by mining.

Remark This unit contains the most southerly populations of *Colophospermum mopane* in South Africa.

References Gertenbach (1983a, b).

SVmp 8 Mopane Gabbro Shrubland

VT 15 Mopani Veld (85%) (Acocks 1953). LR 10 Mopane Bushveld (95%) (Low & Rebelo 1996). KNP 24 *Colophospermum mopane* shrubveld on gabbro (98%) (Gertenbach 1983b).

Distribution Limpopo and Mpumalanga Provinces: Occurs in narrow, irregular and disjunct belts from the Phoda Hills near Bateleur Bushveld Camp in the north, southwards in the vicinity of the Stapelkop Dam and Shimuwini Bushveld Camp, to the Shilawuri Hill area. Also further south in the vicinity of the Shisakashanghondo Dam. Altitude 300–460 m.

Vegetation & Landscape Features Slightly irregular to slightly undulating landscape with numerous outcrops of gabbro. Mainly a low shrub layer with two main structural variations both dominated by *Colophospermum mopane*: a shrubveld with practically no trees and a shrubveld with a few larger shrubs and trees, including *C. mopane* and *Acacia nigrescens*. Species diversity is the highest in the latter variation. The ground layer of both variations is dense.

Geology & Soils The basement rocks of the general area are the Swazian Goudplaats and Makhutswi gneisses. These are intruded by sinuous dykes of Timbavati gabbro that are most significant in this shrubland. Soils are dark, with relatively high clay content. Vertisols occur in areas with concave topography and lithosols on the outcrops. Main soil forms are Milkwood, Mayo, Bonheim and Swartland. Main land types Fa, Ah, Ae, Fb and Ea.

Climate Summer rainfall with very dry winters. MAP about 450–650 mm. Generally a frost-free area. See also climate diagram for SVmp 8 Mopane Gabbro Shrubland.

H.C. Eckhardt

Figure 9.42 SVmp 7 Phalaborwa-Timbavati Mopaneveld: Savanna plains dominated by *Colophospermum* mopane and *Combretum apiculatum* in the Shivulani Kop area of the Kruger National Park, northeast of Phalaborwa.

Important Taxa Tall Tree: *Sclerocarya birrea* subsp. *caffra*. Small Trees: *Acacia exuvialis*, *A. tortilis* subsp. *heteracantha*, *Albizia harveyi*, *Combretum imberbe*, *Dalbergia melanoxylon*. Tall Shrubs: *Colophospermum mopane* (d), *Dichrostachys cinerea*, *Grewia bicolor*, *Tephrosia polystachya*. Low Shrubs: *Commiphora africana*, *Phyllanthus pentandrus*. Woody Climber: *Cissus cornifolia*. Graminoids: *Fingerhuthia africana* (d), *Heteropogon contortus* (d), *Panicum coloratum* (d), *Schmidtia pappophoroides* (d), *Bothriochloa radicans*, *Themeda triandra*, *Urochloa mosambicensis*. Herbs: *Chamaesyce neopolycnemoides*, *Corbichonia decumbens*, *Heliotropium steudneri*.

Conservation Least threatened. Target 19%. Virtually untransformed and about 99% statutorily conserved in the Kruger National Park and the remainder conserved in the private Umbabat Nature Reserve. Erosion is low to very low.

L.W. Powrie

Figure 9.44 SVl 1 Makuleke Sandy Bushveld: Moderately dense bushveld on sandstone ridge east of Mutale, Limpopo Province.

Remarks The vegetation structure is similar to much of that of the SVmp 4 Mopane Basalt Shrubland. The mapped unit follows Gertenbach's (1983b) boundaries. More recent geology maps show the gabbro to be narrower and less continuous than mapped.

References Gertenbach (1978, 1983a, b).

Lowveld

SVl 1 Makuleke Sandy Bushveld

VT 9 Lowveld Sour Bushveld (34%), VT 15 Mopani Veld (21%) (Acocks 1953). LR 21 Sour Lowveld Bushveld (40%), LR 10 Mopane Bushveld (28%) (Low & Rebelo 1996).

Distribution Limpopo and (very slightly into) Mpumalanga Provinces: Flats and hills east of the Soutpansberg, south of Klein Tshipise and Masisi, along the valleys of the Mutale River and mid- to lower Levuvhu River; the Maseya Sandveld and Punda Maria areas of the northern Kruger National Park and as few isolated patches in the park, for example Dzundwini Mountain in the north and a narrow sandstone belt sandwiched between the granite and the basalt reaching the Timbavati Picnic Area in the south. Altitude 300–700 m.

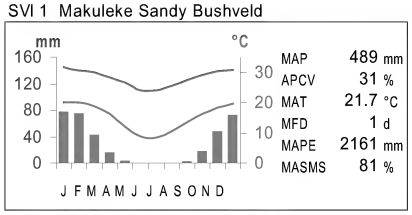
Vegetation & Landscape Features Variable landscapes from low mountains, slightly to extremely irregular plains to hills. A tree savanna (or tall shrub in places) occurs on the deep sands with trees such as *Terminalia sericea*, *Burkea africana*, *Guibourtia conjugata* and *Peltophorum africana* and a moderate to dense ground layer containing, for example, *Andropogon gayanus* and *Digitaria eriantha*. On stony soils the tree savanna includes *Kirkia acuminata*, *Croton gratissimus*, *Combretum apiculatum* and *Diplorhynchus condylocarpon* while the ground layer includes dominant *Digitaria eriantha*, *Panicum maximum* and *Pogonarthria squarrosa*.

Geology & Soils The Soutpansberg Group of sandstones with lesser amounts of conglomerate, shale and basalt is mostly exposed in this area (the Wyllie's Poort, Fundudzi and Nzhelele Formations). Some Karoo Supergroup rocks are also present (Clarens and Letaba Formations). Most of the area has deep sands to shallow sandy lithosols. A few limited areas with heavier soil, particularly in the B-horizon, occur near the western boundary of the Kruger National Park.

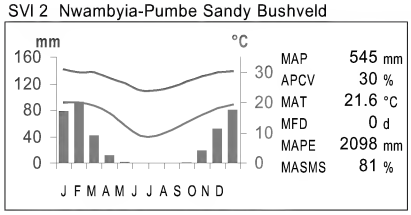
Climate Summer rainfall with very dry winters. MAP about 300–700 mm. Generally a frost-free region, except possibly for higher elevations. Mean monthly maximum and minimum temperatures for Punda Maria 39.7°C and 8.5°C for December and July, respectively. See also climate diagram for SVl 1 Makuleke Sandy Bushveld.

Important Taxa Small Trees: *Burkea africana* (d), *Kirkia acuminata* (d), *Pseudolachnostylis maprouneifolia* (d), *Terminalia sericea* (d), *Afzelia quanzensis*, *Bridelia mollis*, *Combretum apiculatum*, *C. collinum* subsp. *gazense*, *C. zeyheri*, *Croton gratissimus*, *Ficus abutilifolia*, *F. ingens*, *Guibourtia conjugata*, *Hymenocardia ulmoides*, *Lannea schweinfurthii* var. *stuhlmannii*, *Ochna pulchra*, *Ozoroa obovata* var. *elliptica*, *Peltophorum africanum*, *Phyllanthus reticulatus*, *Pterocarpus rotundifolius*, *Stadmannia oppositifolia* subsp. *rhodesica*. Tall Shrubs: *Pteleopsis myrtifolia* (d), *Alchornea laxiflora*, *Boscia angustifolia* var. *corymbosa*, *Dichrostachys cinerea*, *Diospyros lycioides* subsp. *sericea*, *Diplorhynchus condylocarpon*, *Grewia hexamita*, *Gymnosporia mossambicensis*, *Hexalobus monopetalus*, *Monodora junodii* var. *junodii*, *Senna petersiana*, *Steganotaenia araliacea*, *Strychnos madagascariensis*, *Tricalysia junodii*. Low Shrubs: *Agathisanthemum bojeri*, *Hermannia glanduligera*, *Pavetta harborii*. Woody Climbers: *Artabotrys brachypetalus*, *Bauhinia galpinii*, *Cissus cornifolia*, *Rhoicissus revoilii*. Herbaceous Climbers: *Merremia tridentata*, *Rhynchosia totta*. Graminoids: *Andropogon gayanus* (d), *Digitaria eriantha* subsp. *pentzii* (d), *Panicum maximum* (d), *Aristida mollissima* subsp. *argentea*, *A. stipitata* subsp. *graciliflora*, *Brachiaria serrata*, *Bulbostylis hispidula*, *Coleochloa setifera*, *Perotis patens*, *Pogonarthria squarrosa*, *Setaria incrassata*, *Tetrapogon tenellus*, *Tricholaena monachne*. Herbs: *Vahlia capensis* subsp. *vulgaris*, *Vernonia fastigiata*. Geophytic Herb: *Drimia altissima*.

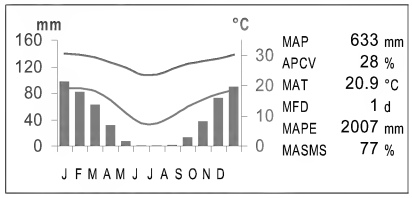
SVI 1 Makuleke Sandy Bushveld



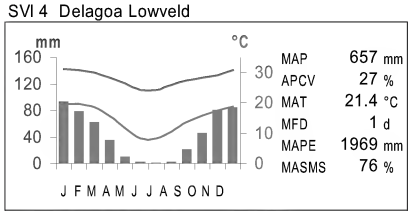
SVI 2 Nwambyia-Pumbe Sandy Bushveld



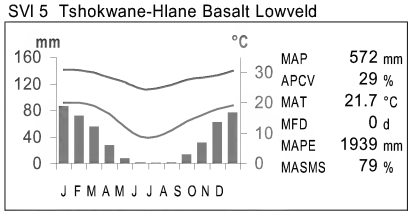
SVI 3 Granite Lowveld



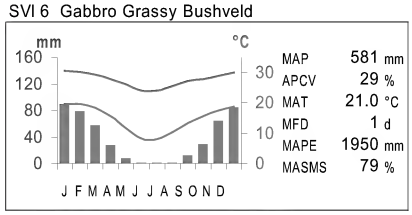
SVI 4 Delagoa Lowveld



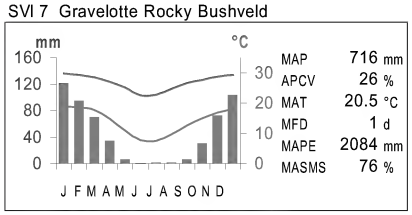
SVI 5 Tshokwane-Hlane Basalt Lowveld



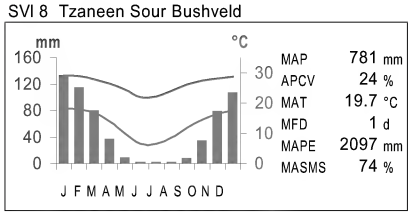
SVI 6 Gabbro Grassy Bushveld



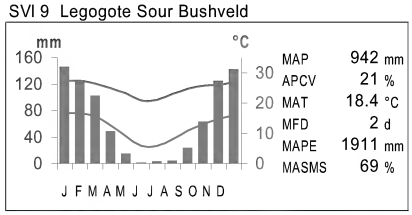
SVI 7 Gravelotte Rocky Bushveld



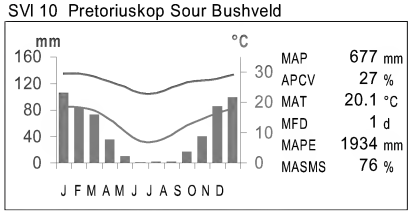
SVI 8 Tzaneen Sour Bushveld



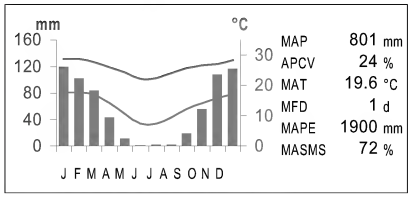
SVI 9 Legogote Sour Bushveld



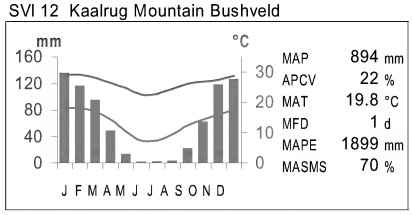
SVI 10 Pretoriuskop Sour Bushveld



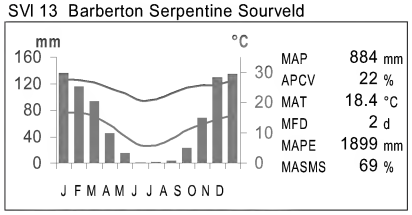
SVI 11 Malelane Mountain Bushveld



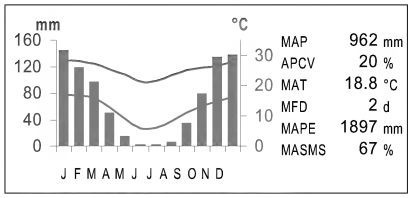
SVI 12 Kaalrug Mountain Bushveld



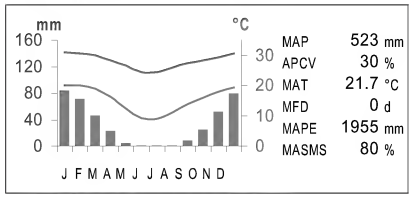
SVI 13 Barberton Serpentine Sourveld



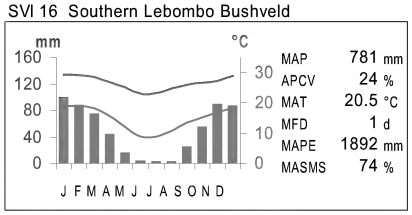
SVI 14 Swaziland Sour Bushveld



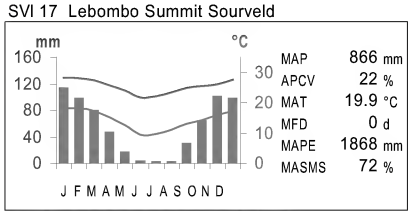
SVI 15 Northern Lebombo Bushveld



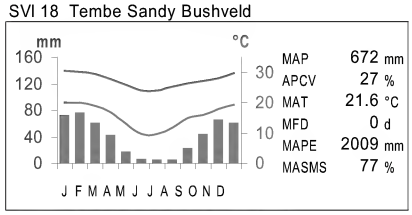
SVI 16 Southern Lebombo Bushveld



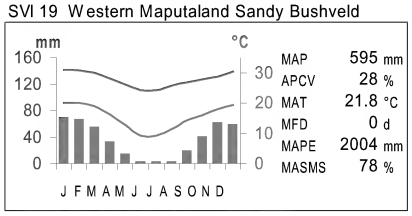
SVI 17 Lebombo Summit Sourveld



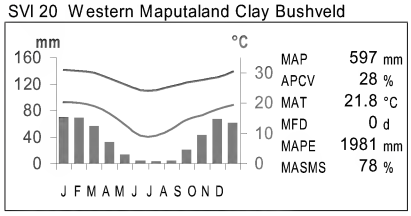
SVI 18 Tembe Sandy Bushveld



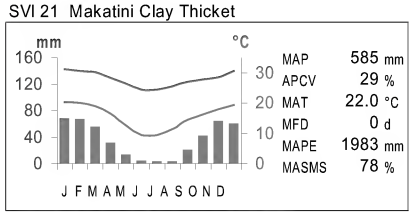
SVI 19 Western Maputaland Sandy Bushveld



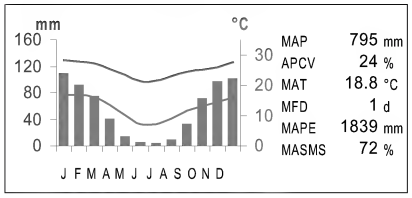
SVI 20 Western Maputaland Clay Bushveld



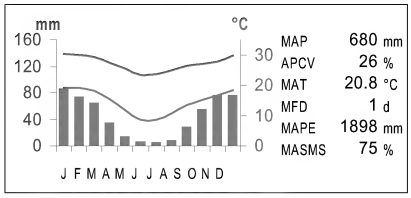
SVI 21 Makatini Clay Thicket



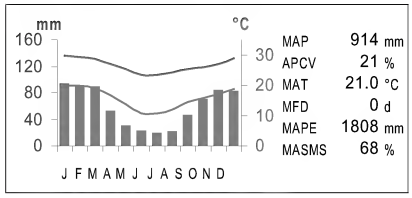
SVI 22 Northern Zululand Sourveld



SVI 23 Zululand Lowveld



SVI 24 Zululand Coastal Thornveld



Biogeographically Important Taxon (Southern distribution limit) Small Tree: *Holarrhena pubescens*.

Endemic Taxa Succulent Shrub: *Euphorbia rowlandii*. Herb: *Ceratotheca saxicola*.

Conservation Vulnerable. Target 19%. About 32% statutorily conserved in the Kruger National Park. Roughly 27% has been transformed, mostly through cultivation. Erosion is moderate to high in places.

Remarks At least two areas of this unit have heavier soil with a clayey B-horizon, and occur on flat to undulating terrain near the western boundary of the Kruger National Park. Despite their heavier soil and that these areas are completely surrounded by vegetation which is overwhelmingly dominated by *Colophospermum mopane*, remarkably few individuals of mopane penetrate these areas. These patches correspond to the *Pterocarpus rotundifolius/Combretum collinum* Woodland of Gertenbach (1983b).

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Figure 9.45 SVl 2 Nwambyia-Pumbe Sandy Bushveld: Open to closed broad-leaved woodland, largely occurring on sandy soils with *Strychnos* species, *Crossopteryx febrifuga* and *Xeroderris stuhlmannii* south of Nwambyia, Kruger National Park.

References Van Rooyen (1978), Van Rooyen et al. (1981a), Gertenbach (1983b).

SVl 2 Nwambyia-Pumbe Sandy Bushveld

VT 15 Mopani Veld (81%) (Acocks 1953). LR 10 Mopane Bushveld (55%) (Low & Rebelo 1996). KNP 32 Nwambia Sandveld (84%) (Gertenbach 1983b).

Distribution Limpopo and Mpumalanga Provinces: Flats well to the east of Punda Maria on the border with Mozambique (the Nwambyia part of this unit). A small patch further south, also on the eastern border, in the vicinity of the Pumbe Guard Post northeast of Satara. Altitude 350–550 m.

Vegetation & Landscape Features Flats with several small pans embedded. Conspicuous is the absence of well-defined drainage channels. Moderately open tall shrubland with few trees. The Nwambyia part consists mainly of *Xeroderris stuhlmannii–Combretum apiculatum* tree savanna and *Terminalia sericea–Pogonarthria squarrosa* tree savanna (Van Rooyen 1978), both with field layers better developed than that of the FOz 8 Sand Forest patch embedded in it. The second variation has many floristic links with SVl 1 Makuleke Sandy Bushveld.

Geology & Soils The Cretaceous Malvernia Formation conglomerate and overlying sandstone form deep yellow to red Quaternary sands of the Hutton and Clovelly soil forms (apedal, freely drained, dystrophic and mesotrophic). The Pumbe part also includes some shallow lithosols (Mispah and Glenrosa soil forms). Land types mainly Ac and Fb.

Climate Summer rainfall with dry winters. MAP about 450–650 mm. Generally a frost-free region. See also climate diagram for SVl 2 Nwambyia-Pumbe Sandy Bushveld.

Important Taxa Tall Trees: *Sclerocarya birrea* subsp. *caffra* (d), *Acacia nigrescens*, *Adansonia digitata*, *Philenoptera violacea*. Small Trees: *Baphia massaiensis* (d), *Combretum apiculatum* (d), *C. zeyheri* (d), *Terminalia sericea* (d), *Afzelia quanzensis*, *Balanites maughamii*, *Boscia albitrunca*, *Cassia abbreviata* subsp. *beareana*, *Combretum collinum* subsp. *taborense*, *C. molle*, *Crossopteryx febrifuga, Dalbergia melanoxylon*, *Lannea schweinfurthii* var. *stuhlmannii*, *Ozoroa engleri*, *Ptaeroxylon obliquum*, *Spirostachys africana*, *Vangueria infausta*. Tall Shrubs: *Grewia microthyrsa* (d), *Pteleopsis myrtifolia* (d), *Tephrosia polystachya* (d), *Vitex ferruginea* (d), *Alchornea laxiflora*, *Dichrostachys cinerea*, *Grewia bicolor*, *G. monticola*, *Phyllanthus parvulus*, *Strychnos madagascariensis*. Low Shrubs: *Agathisanthemum bojeri*, *Aptosimum lineare*, *Melhania forbesii*, *Monechma debile*, *Pavetta catophylla*. Woody Climbers: *Cissus cornifolia*, *Combretum mossambicense*, *Rhynchosia resinosa*. Herbaceous Climber: *Merremia tridentata* (d). Graminoids: *Aristida stipitata* subsp. *graciliflora* (d), *Brachiaria nigropedata* (d), *Digitaria eriantha* subsp. *eriantha* (d), *Eragrostis pallens* (d), *Panicum maximum* (d), *Schmidtia pappophoroides* (d), *Aristida congesta*, *Cymbopogon pospischilii*, *Enneapogon cenchroides*, *Eragrostis superba*, *Heteropogon contortus*, *Perotis patens*, *Pogonarthria squarrosa*, *Tricholaena monachne*, *Urochloa mosambicensis*. Herbs: *Vigna unguiculata* (d), *Coptosperma zygoon*, *Euphorbia tettensis*, *Commelina africana*, *C. erecta*, *Heliotropium steudneri*, *Indigofera filipes*, *I. vicioides*, *Kohautia virgata*.

Biogeographically Important Taxa (Southern distribution limit) Small Trees: *Xeroderris stuhlmannii* (d), *Xylia torreana* (d). Woody Climber: *Hugonia orientalis* (d).

Conservation Least threatened. Target 19%. All statutorily conserved in the Kruger National Park.

Remark This vegetation unit is well represented in Mozambique and extends only as far as 10 km into South Africa.

References Van Rooyen (1978), Van Rooyen et al. (1981a), Gertenbach (1983b).

Figure 9.43 Climate diagrams of Lowveld Bioregion units. Blue bars show the median monthly precipitation. The upper and lower red lines show the mean daily maximum and minimum temperature respectively. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days (days when screen temperature was below 0°C); MAPE: Mean Annual Potential Evaporation; MASMS: Mean Annual Soil Moisture Stress (% of days when evaporative demand was more than double the soil moisture supply).

SVl 3 Granite Lowveld

VT 11 Arid Lowveld (40%), VT 10 Lowveld (38%) (Acocks 1953). LR 19 Mixed Lowveld Bushveld (61%) (Low & Rebelo 1996).

Distribution Limpopo and Mpumalanga Provinces, Swaziland and marginally also KwaZulu-Natal: A north-south belt on the plains east of the escarpment from Thohoyandou in the north, interrupted in the Bolobedu area, continued in the Bitavi area, with an eastward extension on the plains around the Murchison Range and southwards to Abel Erasmus Pass, Mica and Hoedspruit areas to the area east of Bushbuckridge. Substantial parts are found in the Kruger National Park spanning areas east of Orpen Camp southwards through Skukuza and Mkuhlu, including undulating terrain west of Skukuza to the basin of the Mbyamiti River. It continues further southward to the Hectorspruit area with a narrow westward extension up the Crocodile River Valley past Malelane, Kaapmuiden and the Kaap River Valley, entering Swaziland between Jeppe's Reef in the west and the Komati River in the east, through to the area between Manzini and Siphofaneni, including the Grand Valley, narrowing irregularly and marginally entering KwaZulu-Natal near Pongola. Altitude 250–700 m.

Vegetation & Landscape Features Tall shrubland with few trees to moderately dense low woodland on the deep sandy uplands with *Terminalia sericea*, *Combretum zeyheri* and *C. apiculatum* and ground layer including *Pogonarthria squarrosa*, *Tricholaena monachne* and *Eragrostis rigidior*. Dense thicket to open savanna in the bottomlands with *Acacia nigrescens*, *Dichrostachys cinerea*, *Grewia bicolor* in the woody layer. The dense herbaceous layer contains the dominant *Digitaria eriantha*, *Panicum maximum* and *Aristida congesta* on fine-textured soils, while brackish bottomlands support *Sporobolus nitens*, *Urochloa mosambicensis* and *Chloris virgata*. At seep lines, where convex topography changes to concave, a dense fringe of *Terminalia sericea* occurs, with *Eragrostis gummiflua* in the undergrowth.

Geology & Soils From north to south, the Swazian Goudplaats Gneiss, Makhutswi Gneiss and Nelspruit Suite (granite gneiss and migmatite), and further south still, the younger Mpuluzi Granite (Randian) form the major basement geology of the area. Archaean granite and gneiss weather into sandy soils in the uplands and clayey soils with high sodium content in the lowlands.

Climate Summer rainfall with dry winters. MAP from about 450 mm on the eastern flats to about 900 mm near the escarpment in the west. In a north-south direction, MAP of the unit appears to peak in Swaziland. Generally a frost-free region. Mean monthly maximum and minimum temperatures for Skukuza 39.5°C and –0.1°C for January and June, respectively. Corresponding values for Hoedspruit 38.0°C and 3.7°C for January and July, respectively. See also climate diagram for SVl 3 Granite Lowveld.

Important Taxa Tall Trees: *Acacia nigrescens* (d), *Sclerocarya birrea* subsp. *caffra* (d). Small Trees: *Acacia nilotica* (d), *Albizia harveyi* (d), *Combretum apiculatum* (d), *C. imberbe* (d), *C. zeyheri* (d), *Ficus stuhlmannii* (d), *Peltophorum africanum* (d), *Pterocarpus rotundifolius* (d), *Terminalia sericea* (d), *Acacia exuvialis*, *A. gerrardii*, *Bolusanthus speciosus*, *Cassia abbreviata* subsp. *beareana*, *Combretum collinum* subsp. *suluense*, *Dalbergia melanoxylon*, *Gymnosporia glaucophylla*, *Lannea schweinfurthii* var. *stuhlmannii*, *Pavetta schumanniana*, *Plectroniella armata*, *Terminalia prunioides*. Tall Shrubs: *Combretum hereroense* (d), *Dichrostachys cinerea* (d), *Euclea divinorum* (d), *Strychnos madagascariensis* (d), *Gardenia volkensii*, *Hibiscus micranthus*, *Tephrosia polystachya*. Low Shrubs: *Abutilon austro-africanum*, *Agathisanthemum bojeri*, *Aptosimum lineare*, *Barleria elegans*, *Clerodendrum ternatum*, *Commiphora africana*, *Gossypium herbaceum* subsp. *africanum*, *Pavonia burchellii*. Woody Climber: *Sphedamnocarpus pruriens* subsp. *pruriens*. Herbaceous Climber: *Rhynchosia totta*. Graminoids: *Brachiaria nigropedata* (d), *Digitaria eriantha* subsp. *eriantha* (d), *Eragrostis rigidior* (d), *Melinis repens* (d), *Panicum maximum* (d), *Pogonarthria squarrosa* (d), *Aristida congesta*, *Bulbostylis hispidula*, *Chloris mossambicensis*, *Enneapogon cenchroides*, *Heteropogon contortus*, *Leptochloa eleusine*, *Perotis patens*, *Schmidtia pappophoroides*, *Sehima galpinii*, *Tricholaena monachne*, *Urochloa mosambicensis*. Herbs: *Achyranthes aspera*, *Aspilia mossambicensis*, *Becium filamentosum*, *Chamaecrista absus*, *Commelina benghalensis*, *C. erecta*, *Cucumis africanus*, *Evolvulus alsinoides*, *Heliotropium strigosum*, *Hermbstaedtia odorata*, *Hibiscus praeteritus*, *Indigofera filipes, I. sanguinea*, *Kohautia virgata*, *Kyphocarpa angustifolia*, *Leucas glabrata*, *Ocimum gratissimum*, *Phyllanthus maderaspatensis*, *Pupalia lappacea*, *Vahlia capensis* subsp. *vulgaris*, *Waltheria indica*. Succulent Herbs: *Orbea rogersii*, *Stapelia leendertziae*.

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Figure 9.46 SVl 3 Granite Lowveld: Moderately open savanna dominated by *Sclerocarya birrea*, *Combretum apiculatum* and *C. zeyheri* south of Skukuza, Kruger National Park.

Conservation Vulnerable. Target 19%. Some 17% statutorily conserved in the Kruger National Park. About the same amount conserved in private reserves mainly the Selati, Klaserie, Timbavati, Mala Mala, Sabi Sand and Manyeleti Reserves. More than 20% already transformed, mainly by cultivation and by settlement development. Erosion is very low to moderate.

Remark Further research may reveal a need to differentiate the northern from the southern parts of this unit.

References Bredenkamp (1982, 1985, 1986a, 1987), Bredenkamp et al. (1983, 1993), Coetzee (1983), Gertenbach (1983b), Bredenkamp & Theron (1985, 1988, 1990, 1991), Witkowski & O'Connor (1996).

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Figure 9.47 SVl 4 Delagoa Lowveld: Heavily utilised area surrounded by *Acacia welwitschii* tending towards thickets southwest of Satara, Kruger National Park.

SVl 4 Delagoa Lowveld

VT 10 Lowveld (87%) (Acocks 1953). LR 19 Mixed Lowveld Bushveld (59%) (Low & Rebelo 1996).

Distribution Mpumalanga Province, Swaziland and marginally into KwaZulu-Natal Province: A narrow strip on plains immediately east of the SVl 3 Granite Lowveld from the Nsemani River west of Satara in the Kruger National Park southwards to immediately west of Lower Sabie Camp to the Pomba Guard Post west of Crocodile Bridge Camp to the Strydom Block in the south. Also a band in Swaziland from Mhlume in the north to Onverwacht Border Post in the south, extending marginally into KwaZulu-Natal at Pongola. Altitude 150–450 m.

Vegetation & Landscape Features Dense tree or tall shrub layer dominated by *Acacia welwitschii*, often forming thickets. Herb layer has in addition to grass species a wide variety of forbs. Areas are often heavily grazed which sometimes drastically reduces the grass cover.

Geology & Soils Karoo Supergroup shale and lesser sandstone layers are punctuated by sheets and dykes of Jurassic dolerite. Soils (Sterkspruit, Swartland and Estcourt soil forms) are rich in sodium and very susceptible to erosion. Land types include Dc and Ea.

Climate Summer rainfall with dry winters. MAP about 450–850 mm. Generally a frost-free region. See also climate diagram for SVl 4 Delagoa Lowveld.

Important Taxa Small Trees: *Acacia senegal* var. *rostrata* (d), *A. welwitschii* subsp. *delagoensis* (d), *Albizia petersiana* (d), *Schotia capitata* (d), *Spirostachys africana* (d), *Pappea capensis*. Tall Shrubs: *Euclea divinorum* (d), *Maerua parvifolia* (d), *Boscia mossambicensis*, *Dichrostachys cinerea*, *Ehretia rigida* subsp. *rigida*, *Flueggea virosa*, *Grewia bicolor*, *Rhus gueinzii*. Low Shrubs: *Abutilon austroafricanum*, *Justicia flava*, *Zanthoxylum humile*. Woody Climbers: *Cordia ovalis* (d), *Capparis tomentosa*. Graminoids: *Chloris virgata* (d), *Panicum coloratum* (d), *P. maximum* (d), *Sporobolus nitens* (d), *Aristida congesta*, *Chloris roxburghiana*, *Dactyloctenium aegyptium*, *Tragus berteronianus*. Herbs: *Blepharis integrifolia*, *Kyphocarpa angustifolia*, *Ruellia patula*. Succulent Herb: *Aloe parvibracteata*.

Conservation Vulnerable. Target 19%. About 18% statutorily conserved in the Kruger National Park. Some 33% transformed, almost all by cultivation.

References Coetzee (1983), Gertenbach (1983b).

SVl 5 Tshokwane-Hlane Basalt Lowveld

VT 11 Arid Lowveld (56%) (Acocks 1953). LR 20 Sweet Lowveld Bushveld (69%) (Low & Rebelo 1996).

Distribution Mpumalanga Province and Swaziland (and very slightly into Limpopo Province): On plains immediately west of the Lebombo Mountains from Balule and Satara Camps in Kruger National Park in the north, through Tshokwane, Lower Sabie and Crocodile Bridge Camps, Komatipoort to around Ngwenyeni in the south. In Swaziland it occurs from Vuvulane Settlement in the north, through Hlane Game Sanctuary to a point in the south approximately halfway between Siteki and Big Bend. Altitude 180–400 m.

Vegetation & Landscape Features Usually fairly flat plains with open tree savanna, often dominated by tall *Sclerocarya birrea* and *Acacia nigrescens* with a moderately developed shrub layer and a dense herbaceous layer. On some sloping areas with shallower soils, trees are stunted (e.g. *A. nigrescens*).

Geology & Soils The Letaba Formation basalts of the Karoo Supergroup in this area give rise to black, brown or red clayey soils, usually not more the 1 m deep. Vertisols, such as the Arcadia soil form, occur in low-lying areas and concave plains. Land types mainly Ea with some Dc.

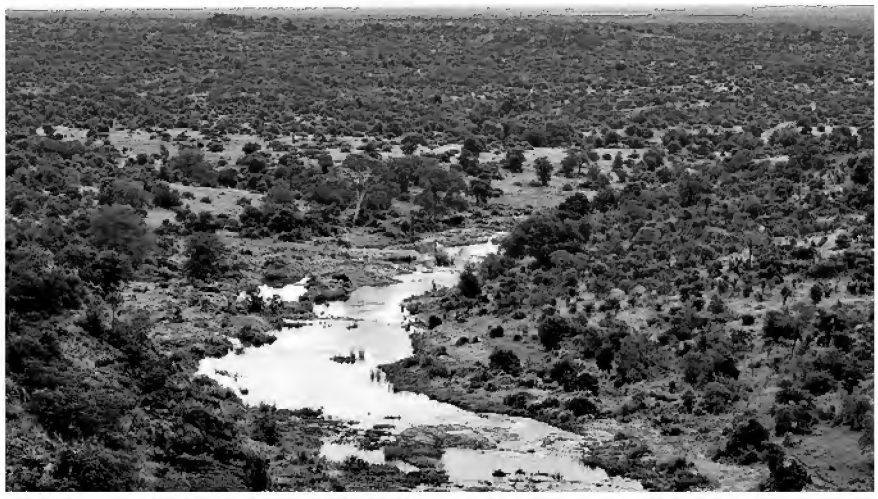

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Figure 9.48 SVl 5 Tshokwane-Hlane Basalt Lowveld: Deciduous closed woodland occurring on clay flats with *Acacia gerrardii*, *A. tortilis*, *Combretum hereroense* and *C. imberbe* looking over the Nwanetsi River, Kruger National Park.

Climate Summer rainfall with dry winters. MAP about 400–800 mm in the southernmost part in Swaziland. Mean monthly maximum and minimum temperatures for Satara (in the north of the unit) 40.2°C and 4.2°C for January and June, respectively. See also climate diagram for SVl 5 Tshokwane-Hlane Basalt Lowveld.

Important Taxa Tall Trees: *Acacia nigrescens* (d), *Sclerocarya birrea* subsp. *caffra* (d), *Philenoptera violacea*. Small Trees: *Acacia borleae*, *A. gerrardii*, *A. nilotica*, *A. tortilis* subsp. *heteracantha*, *Albizia harveyi*, *Combretum hereroense*, *C. imberbe*, *Lannea schweinfurthii* var. *stuhlmannii*, *Peltophorum africanum*, *Pterocarpus rotundifolius*. Tall Shrubs: *Dichrostachys cinerea*, *Grewia bicolor*, *Gymnosporia maranguensis*, *Rhus gueinzii*. Low Shrubs: *Acalypha segetalis*, *Dicoma tomentosa*, *Hermannia glanduligera*, *Justicia flava*, *J. protracta* subsp. *protracta*, *Seddera suffruticosa*, *Tragia dioica*. Herbaceous Climber: *Commicarpus plumbagineus*. Graminoids: *Bothriochloa radicans* (d), *Digitaria eriantha* subsp. *eriantha* (d), *Panicum coloratum* (d), *P. maximum* (d), *Themeda triandra* (d), *Urochloa mosambicensis* (d), *Aristida congesta*, *Cenchrus ciliaris*, *Eragrostis superba*, *Heteropogon contortus*. Herbs: *Chamaecrista mimosoides*, *Gisekia africana*, *Thunbergia dregeana*. Succulent Herbs: *Aloe zebrina*, *Orbea paradoxa, O. rogersii*.

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Figure 9.49 SVl 6 Gabbro Grassy Bushveld: Very open low grassy savanna with *Acacia nigrescens* and *Albizia harveyi* near Skipberg southeast of Pretoriuskop, Kruger National Park.

Endemic Taxon Low Shrub: *Boscia foetida* subsp. *minima*.

Conservation Least threatened. Target 19%. About 64% statutorily conserved mainly in the Kruger National Park, but also in the Mlawula Nature Reserve. In addition, over 3% conserved mainly in the Hlane Game Sanctuary. About 17% transformed, almost all by cultivation.

Remarks Different parts of this unit can show different rates of change over years, including some parts with very little change (Coetzee et al. 1977). Mapped as part of this unit is the small area (3% of the unit) east of Kumana waterhole, south of Satara (Kumana Sandveld of Gertenbach 1983b), which is on sandstone, but contains dolerite intrusions with clayey soil as well as some surface shales with sodium-saturated soil.

References Coetzee et al. (1977), Gertenbach & Potgieter (1978), Coetzee (1983), Gertenbach (1983b).

SVl 6 Gabbro Grassy Bushveld

VT 11 Arid Lowveld (60%) (Acocks 1953). LR 20 Sweet Lowveld Bushveld (52%) (Low & Rebelo 1996). KNP 19 Thornveld on gabbro (96%) (Gertenbach 1983b).

Distribution Mpumalanga Province: Flats and hills mainly in the Kruger National Park in isolated patches from Orpen Camp in the north, southwards including Rooigras Vlakte (northeast of Skukuza) and some areas stretching from north of Pretoriuskop to around Afsaal in the south. Altitude 200–550 m.

Vegetation & Landscape Features Open savanna with a dense grass cover (with dominants including *Themeda triandra*) with a few scattered trees and shrubs. Sparser grass cover is encountered on shallow soils.

Geology & Soils The distribution of this bushveld closely follows the sinuous intrusions of the Timbavati gabbro (Mokolian Erathem). The unit is also mapped on surrounding potassic granite and gneiss of Archaean basement and the gneiss and migmatite of the Nelspruit Suite (also Archaean). Dark vertic clay soils (20–50% clay) often swell and shrink. Loose rock is often present on the surface. Some shallow lithosols occur in places. Where gabbro is in contact with the adjacent granite, a mixed soil sometimes develops with a gabbro-derived A-horizon overlying a granite-derived B-horizon. Land types mainly Fb and Dc.

Climate Summer rainfall with dry winters. MAP about 500–650 mm. Generally a frost-free region. See also climate diagram for SVl 6 Gabbro Grassy Bushveld.

Important Taxa Tall Trees: *Acacia nigrescens* (d), *Sclerocarya birrea* subsp. *caffra*. Small Trees: *Acacia tortilis* subsp. *heteracantha*, *Bolusanthus speciosus*, *Dalbergia melanoxylon*, *Lannea schweinfurthii* var. *stuhlmannii*, *Ziziphus mucronata*. Tall Shrubs: *Flueggea virosa*, *Grewia bicolor*, *Ormocarpum trichocarpum*, *Tephrosia polystachya*. Low Shrubs: *Abutilon austro-africanum*, *Seddera suffruticosa*, *Sida rhombifolia*. Graminoids: *Chloris virgata* (d), *Ischaemum afrum* (d), *Setaria incrassata* (d), *Themeda triandra* (d), *Bothriochloa radicans*, *Cenchrus ciliaris*, *Cymbopogon pospischilii*, *Digitaria eriantha* subsp. *eriantha*, *Enneapogon cenchroides*, *Eragrostis superba*, *Panicum maximum*, *Schmidtia pappophoroides*, *Sorghum versicolor*, *Sporobolus nitens*, *Urochloa mosambicensis*. Herbs: *Heliotropium steudneri*, *Ipomoea crassipes*, *Kyphocarpa angustifolia*. Succulent Herb: *Aloe zebrina*.

Conservation Least threatened. Target 19%. Altogether 96% statutorily conserved in the Kruger National Park and the remainder is conserved in private reserves (Timbavati and Manyeleti). Very little transformed and erosion is low.

Remarks The mapped unit follows Gertenbach's (1983b) boundaries. More recent geology maps show the gabbro to be narrower than mapped. A few areas of gabbro just outside the southern Kruger National Park have not been depicted on our map.

References Gertenbach (1978, 1983b), Bredenkamp & Deutschländer (1994, 1995).

SVl 7 Gravelotte Rocky Bushveld

VT 11 Arid Lowveld (59%) (Acocks 1953). LR 19 Mixed Lowveld Bushveld (58%) (Low & Rebelo 1996).

Distribution Limpopo Province: The Murchison Range in the Gravelotte area including surrounding mountains and hills including Ga-Mashishimale north of Mica and Seribana, and extending northwards towards Thohoyandou as isolated hills including Mangombe and Sionwe. Altitude 450–950 m (with the highest peaks reaching 1 025 m).

Vegetation & Landscape Features Open deciduous to semi-deciduous woodland on rocky slopes and inselbergs, contrasting strongly with the surrounding plains.

Geology & Soils The varied geology is largely composed of schist and amphibolite of the Gravelotte and Giyani Groups, with a few quartzitic and granitic hills. Miscellaneous, often shallow, soils with Glenrosa and Mispah forms common. Land types mainly Ib, Fa, Ae and Fb.

Climate Summer rainfall with dry winters. MAP about 500 mm in the east to about 900 mm in the west, with the higher rainfall on the higher mountains. Frost very infrequent. See also climate diagram for SVl 7 Gravelotte Rocky Bushveld.

Important Taxa Tall Tree: *Pterocarpus angolensis*. Small Trees: *Acacia caffra* (d), *Croton gratissimus* (d), *Cussonia natalensis* (d), *Ficus tettensis* (d), *Kirkia acuminata* (d), *Berchemia zeyheri*, *Bridelia mollis*, *Combretum apiculatum*, *C. molle*, *Dombeya rotundifolia*, *Englerophytum magalismontanum*, *Faurea saligna*, *Ficus abutilifolia*, *F. burkei*, *Heteropyxis natalensis*, *Ochna natalitia*, *Pavetta schumanniana*, *Rhus leptodictya*, *Schrebera alata* (woodland form), *Sterculia rogersii*, *Vangueria infausta*. Succulent Tree: *Euphorbia cooperi*. Tall Shrubs: *Steganotaenia araliacea* (d), *Coptosperma supra-axillare*, *Hexalobus monopetalus*, *Mundulea sericea*, *Pouzolzia mixta*, *Psydrax livida*. Low Shrubs: *Barleria affinis*, *B. lancifolia*, *B. saxatilis*, *Psiadia punctulata*. Woody Climbers: *Cocculus hirsutus*, *Sphedamnocarpus pruriens* subsp. *pruriens*. Graminoids: *Brachiaria serrata* (d), *Panicum maximum* (d), *Andropogon schirensis*, *Brachiaria nigropedata*, *Cymbopogon caesius*, *Eustachys paspaloides*, *Heteropogon contortus*, *Loudetia simplex*, *Setaria sphacelata*. Herb: *Vernonia natalensis*. Succulent Herb: *Stapelia gigantea*.

Endemic Taxon Small Tree: *Encephalartos dyerianus*.

Conservation Least threatened. Target 19%. None conserved in statutory conservation areas. Some 7% conserved in a small proportion of the area in the northern part of the Selati Game Reserve. Conservation of this unit is promoted due to the land use of game and cattle ranching and due to its low agronomic potential. About 15% transformed, mainly by cultivation and some development of settlements. Erosion is very low to moderate.

Reference M.C. Lötter & J.E. Burrows (unpublished data).

SVl 8 Tzaneen Sour Bushveld

VT 9 Lowveld Sour Bushveld (80%) (Acocks 1953). LR 21 Sour Lowveld Bushveld (59%) (Low & Rebelo 1996).

Distribution Limpopo Province: A band extending along the footslopes and hills of the northeastern escarpment, from the Soutpansberg Mountains in the north via Tzaneen and narrowing to the Abel Erasmus Pass area in the south. Altitude 600–1 000 m and higher in places.

Vegetation & Landscape Features Deciduous, tall open bushveld (parkland) with a well-developed, tall grass layer, occurring on low to high mountains with undulating plains mainly at the base of, and on the lower to middle slopes of the northeastern escarpment.

Geology & Soils The potassium-poor gneisses of the Goudplaats gneiss (Swazian Erathem) and an Archaean granite dyke underlie most of this area. Shales and quartzite of the Wolkberg Group are present, but not common. Soils are Mispah, Glenrosa or Hutton forms, shallow to deep, sandy or gravelly and well-drained. Land types Fa, Ab, Ae and Ia.

Climate Summer rainfall with dry winters. MAP from about 550 mm on the footslopes of the escarpment in the east to about 1 000 mm, where it borders grassland at higher altitudes to the west. Frost infrequent, but occasional at higher altitude. Mean monthly maximum and minimum temperatures for Tzaneen 36.4°C and 3.9°C for January and June, respectively. Corresponding values for Levubu-Agr 36.4°C and 5.7°C for October and July, respectively. See also climate diagram for SVl 8 Tzaneen Sour Bushveld.

Important Taxa Tall Trees: *Pterocarpus angolensis*, *Sclerocarya birrea* subsp. *caffra*. Small Trees: *Acacia polyacantha* (d), *Albizia versicolor* (d), *Ficus sansibarica* (d), *Parinari curatellifolia* (d), *Piliostigma thonningii* (d), *Pterocarpus rotundifolius* (d), *Trichilia emetica* (d), *Acacia davyi*, *A. sieberiana* var. *woodii*, *Antidesma venosum*, *Catha edulis*, *Faurea rochetiana*, *F. saligna*, *Ficus*

L. Mucina

Figure 9.50 SVl 8 Tzaneen Sour Bushveld: The legendary Modjadji 'Forest' housing thousands of old specimens of *Encephalartos transvenosus*, protected by Her Majesty the Rain Queen of the Bo-Lobedu people near Ga-Modjadji, northeast of Tzaneen.

burkei, *F. petersii*, *Heteropyxis natalensis*, *Peltophorum africanum*, *Terminalia sericea*, *Vernonia colorata*. Tall Shrubs: *Olea europaea* subsp. *africana*, *Pseudarthria hookeri* var. *hookeri*, *Rhus pentheri*, *Triumfetta pilosa* var. *tomentosa*. Low Shrubs: *Agathisanthemum bojeri*, *Barleria elegans*, *Dicliptera clinopodia*, *Flemingia grahamiana*, *Indigofera filipes*, *Polygala producta*. Woody Climbers: *Bauhinia galpinii*, *Pterolobium stellatum*. Graminoids: *Cymbopogon caesius* (d), *C. nardus* (d), *Hyparrhenia cymbaria* (d), *H. poecilotricha* (d), *Hyperthelia dissoluta* (d), *Alloteropsis semialata* subsp. *semialata*, *Andropogon schirensis*, *Bothriochloa bladhii*, *Monocymbium ceresiiforme*, *Paspalum scrobiculatum*, *Schizachyrium sanguineum*, *Themeda triandra*. Herb: *Waltheria indica*.

W.L. McCleland

Figure 9.51 SVl 9 Legogote Sour Bushveld: A particularly open form of this type, namely Short Sparse Woodland with scattered Short Thicket (*sensu* Edwards 1983), extensively represented on crests and slopes. Dominant trees include *Acacia sieberiana*, *A. davyi*, *Dichrostachys cinerea* and *Rhus pyroides* with grasses *Hyperthelia dissoluta*, *Hyparrhenia* species, and shorter grass species such as *Themeda triandra* and *Loudetia simplex*. On the Farm Dingwell southwest of White River.

Conservation Endangered. Target 19%. Only a little over 1% statutorily conserved, almost all in the Lekgalameetse Nature Reserve, and about 2% conserved in private reserves such as the Selati Game Reserve and Wolkberg (Serala) Wilderness Area. About 41% transformed mainly by cultivation (29%) and plantations (9%). The higher-lying parts of this unit have been heavily afforested with tree plantations while the lower-lying areas are under agricultural and horticultural crops. Scattered alien plants include *Solanum mauritianum*, *Melia azedarach* and *Caesalpinia decapetala*. The subtropical climate is conducive to the spread of *Chromolaena odorata*, *Lantana camara* and *Psidium guajava*. Erosion is very variable—from very low to high in some areas.

Remarks This unit has several subtropical elements such as *Acacia polyacantha* and *Trichilia emetica*. It is very similar to SVl 9 Legogote Sour Bushveld, but the latter has a cooler climate and different floristic elements. At places on the footslopes, this vegetation becomes very dense and is transitional to forest in kloofs on the eastern slopes of the Drakensberg. *A. ataxacantha* and *Trema orientalis* are prominent pioneer species here. This unit is also rich in fig species.

References Scheepers (1977), Acocks (1988), Stalmans (1990).

SVl 9 Legogote Sour Bushveld

VT 9 Lowveld Sour Bushveld (56%) (Acocks 1953). LR 21 Sour Lowveld Bushveld (90%) (Low & Rebelo 1996).

Distribution Mpumalanga and Limpopo Provinces: Lower eastern slopes and hills of the northeastern escarpment from Mariepskop in the north through White River to the Nelspruit area extending westwards up the valleys of the Crocodile, Elands and Houtbosloop Rivers and terminating in the south in the Barberton area. Altitude 600–1 000 m and higher in places.

Vegetation & Landscape Features Gently to moderately sloping upper pediment slopes with dense woodland including many medium to large shrubs often dominated by *Parinari curatellifolia* and *Bauhinia galpinii* with *Hyperthelia dissoluta* and *Panicum maximum* in the undergrowth. Short thicket dominated by *Acacia ataxacantha* occurs on less rocky sites. Exposed granite outcrops have low vegetation cover, typically with *Englerophytum magalismontanum*, *Aloe petricola* and *Myrothamnus flabellifolia*.

Geology & Soils Most of the area is underlain by gneiss and migmatite of the Nelspruit Suite, but the southern part occurs on the potassium-poor rocks of the Kaap Valley Tonalite (both Swazian Erathem). The westernmost parts of the distribution are found in Pretoria Group shale and quartzite (Vaalian). Archaean granite plains with granite inselbergs and large granite boulders also occur. Soils are of Mispah, Glenrosa and Hutton forms, shallow to deep, sandy or gravelly and well drained. Diabase intrusions are common, giving rise to Hutton soils. Land types Ab, Fa and Ae.

Climate Summer rainfall with dry winters. MAP from about 700 mm on the footslopes of the escarpment in the east to about 1 150 mm where it borders on grassland at higher altitude to the west. Frost infrequent to occasional at higher altitudes. Mean monthly maximum and minimum temperatures for Nelspruit 35.7°C and 1.6°C for October and July, respectively. Corresponding values for Barberton-Agr 36.0°C and 0.8°C for October and June, respectively. Both weather stations lie at the eastern edge of the unit at lower altitude. See also climate diagram for SVl 9 Legogote Sour Bushveld.

Important Taxa Tall Trees: *Pterocarpus angolensis* (d), *Sclerocarya birrea* subsp. *caffra* (d). Small Trees: *Acacia davyi* (d), *A. sieberiana* var. *woodii* (d), *Combretum zeyheri* (d), *Erythrina latissima* (d), *Parinari curatellifolia* (d), *Terminalia sericea* (d), *Trichilia emetica* (d), *Vernonia amygdalina* (d), *Acacia caffra*, *Antidesma venosum*, *Erythroxylum emarginatum*, *Faurea rochetiana*, *F. saligna*, *Ficus burkei*, *F. glumosa*, *F. ingens*, *F. petersii*, *Heteropyxis natalensis*, *Peltophorum africanum*, *Piliostigma thonningii*, *Pterocarpus rotundifolius*, *Schotia brachypetala*. Succulent Tree: *Euphorbia ingens*. Tall Shrubs: *Diospyros lycioides* subsp. *sericea*, *Erythroxylum delagoense*, *Olea europaea* subsp. *africana*, *Pachystigma macrocalyx*, *Pseudarthria hookeri* var. *hookeri*, *Rhus pentheri*. Low Shrubs: *Diospyros galpinii* (d), *Flemingia grahamiana* (d), *Agathisanthemum bojeri*, *Eriosema psoraleoides*, *Gymnosporia heterophylla*, *Hemizygia punctata*,

Indigofera filipes, *Myrothamnus flabellifolius*, *Rhus rogersii*. Succulent Shrubs: *Aloe petricola*, *Euphorbia vandermerwei*, *Huernia kirkii*. Woody Climbers: *Acacia ataxacantha* (d), *Bauhinia galpinii* (d), *Helinus integrifolius*, *Sphedamnocarpus pruriens* subsp. *pruriens*. Graminoids: *Bothriochloa bladhii* (d), *Cymbopogon caesius* (d), *C. nardus* (d), *Hyparrhenia cymbaria* (d), *H. poecilotricha* (d), *Hyperthelia dissoluta* (d), *Panicum maximum* (d), *Andropogon schirensis*, *Paspalum scrobiculatum*, *Schizachyrium sanguineum*. Herbs: *Gerbera ambigua*, *G. viridifolia*, *Hemizygia persimilis*, *Hibiscus sidiformis*, *Ocimum gratissimum*, *Waltheria indica*. Succulent herbs: *Orbea carnosa* subsp. *carnosa*, *Stapelia gigantea*. Geophytic Herbs: *Gladiolus hollandii*, *Hypoxis rigidula*.

Endemic Taxon Succulent Herb: *Aloe simii*.

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Figure 9.52 SVl 10 Pretoriuskop Sour Bushveld: Typical savanna dominated mainly by *Terminalia sericea* with *Pterocarpus angolensis* north of Pretoriuskop, Kruger National Park.

Conservation Endangered. Target 19%. About 2% statutorily conserved mainly in the Bosbokrand and Barberton Nature Reserves; at least a further 2% is conserved in private reserves including the Mbesan and Kaapsehoop Reserves and Mondi Cycad Reserve. It has been greatly transformed (50%), mainly by plantations and also by cultivated areas and urban development. Scattered alien plants include *Lantana camara*, *Psidium guajava* and *Solanum mauritianum*. Erosion is very low to moderate.

Remark At places on the footslopes this vegetation becomes very dense and is transitional to forest in kloofs on the eastern slopes of the escarpment.

References Van der Schijff & Schoonraad (1971), Deall (1985), Acocks (1988), Deall et al. (1989).

SVl 10 Pretoriuskop Sour Bushveld

VT 10 Lowveld (94%) (Acocks 1953). LR 21 Sour Lowveld Bushveld (78%) (Low & Rebelo 1996).

Distribution Mpumalanga Province: From around Hazyview and Pretoriuskop Camp in the southwestern part of the Kruger National Park to the Malekutu area. Also in the Crocodile Estates area between Nelspruit and Crocodile Gorge. Altitude 400–700 m.

Vegetation & Landscape Features Mainly uplands with open tree savanna dominated by *Terminalia sericea* and *Dichrostachys cinerea* with relatively few low shrubs, grassy layer dense and dominated by sour grasses such as *Hyperthelia dissoluta*, *Elionurus muticus* and *Hyparrhenia hirta*. Grass composition changes somewhat on the midslopes, and in the narrow bottomlands dominant species include *Acacia nilotica*, *A. gerrardii* and *A. tortilis*, *Digitaria eriantha*, *Eragrostis superba* and *Aristida congesta*.

Geology & Soils Granite and gneiss of the Nelspruit Suite weathering to a shallow, leached, red to yellow-brown sand to sandy loam of the Glenrosa, Hutton and Clovelly forms. Land types Ae, Ab, Ba and Fb.

Climate Summer rainfall and dry winters. MAP about 550–800 mm. Frost infrequent. Mean monthly maximum and minimum temperatures for Pretoriuskop are 37.3°C and 5.2°C for October and July, respectively. See also climate diagram for SVl 10 Pretoriuskop Sour Bushveld.

Important Taxa Tall Tree: *Sclerocarya birrea* subsp. *caffra* (d). Small Trees: *Combretum apiculatum* (d), *C. zeyheri* (d), *Peltophorum africanum* (d), *Piliostigma thonningii (d)*, *Terminalia sericea* (d), *Antidesma venosum*, *Combretum collinum* subsp. *gazense*, *C. molle*, *Ficus petersii*, *Parinari curatellifolia*, *Pterocarpus angolensis*, *Ximenia caffra*. Tall Shrubs: *Dichrostachys cinerea* (d), *Gymnosporia senegalensis* (d), *Strychnos madagascariensis* (d), *Grewia bicolor*, *G. monticola*, *Strychnos spinosa*, *Turraea nilotica*. Low Shrubs: *Agathisanthemum bojeri*, *Aptosimum lineare*, *Barleria obtusa*, *Gymnosporia glaucophylla*, *Melhania rehmannii*, *Sida chrysantha*. Succulent Shrub: *Aloe petricola*. Woody climber: *Bauhinia galpinii*. Graminoids: *Aristida congesta* (d), *Digitaria eriantha* subsp. *eriantha* (d), *Elionurus muticus* (d), *Eragrostis rigidior* (d), *Heteropogon contortus* (d), *Hyparrhenia hirta* (d), *Hyperthelia dissoluta* (d), *Panicum coloratum* (d), *Pogonarthria squarrosa* (d), *Bothriochloa radicans*, *Diheteropogon amplectens*, *Eragrostis atrovirens*, *E. lappula*, *Hyparrhenia filipendula*, *Melinis repens*, *Perotis patens*, *Setaria sphacelata*, *Urochloa mosambicensis*. Herbs: *Chamaecrista mimosoides*, *Tricliceras glanduliferum*.

Conservation Least threatened. Target 19%. Some 40% statutorily conserved in the Kruger National Park. A very small area is also conserved in the private Mthethomusha Nature Reserve. About 16% transformed by cultivation and by development of settlements. Alien plants include *Opuntia stricta*, *Lantana camara* and *Psidium guajava*. Erosion is very low to moderate.

Remark This vegetation is related to the SVl 9 Legogote Sour Bushveld, but is drier.

Reference Gertenbach (1983b).

SVl 11 Malelane Mountain Bushveld

VT 10 Lowveld (80%) (Acocks 1953). LR 21 Sour Lowveld Bushveld (75%) (Low & Rebelo 1996).

Distribution Mpumalanga Province: High-lying area north of Malelane and Kaapmuiden including Berg-en-Dal Rest Camp area as far north as the area of the hill Sithongwane in the

Kruger National Park. Also includes the Krokodilpoortberge both north and south of the Crocodile Gorge. Altitude from 400 to over 1 000 m in places.

Vegetation & Landscape Features Open savanna on mountains and higher-lying slopes, with an open to dense, short mountain bushveld on rocky outcrops and lower-lying areas. Altitude and aspect are important in determining species composition in this mountainous terrain.

Geology & Soils Granite and gneiss, mostly of the Nelspruit Suite, forming hills with large boulders, with shallow, coarse, sandy lithosols, largely comprised of Glenrosa or Mispah soil types. Land types Fa, Fb and Ib.

Climate Summer rainfall with dry winters. MAP about 600–1 100 mm, increasing with altitude. Mountain tops experience occasional mist. Frost infrequent to occasional at higher altitudes. See also climate diagram for SVl 11 Malelane Mountain Bushveld.

Important Taxa **Low-lying closed savanna:** Tall Tree: *Pterocarpus angolensis* (d). Small Trees: *Acacia caffra* (d), *A. davyi* (d), *Combretum molle* (d), *Dombeya rotundifolia* (d), *Faurea saligna* (d), *Heteropyxis natalensis* (d), *Kirkia wilmsii* (d), *Sterculia murex* (d), *Acacia swazica*, *Combretum collinum* subsp. *suluense*, *C. zeyheri*, *Englerophytum magalismontanum*, *Ficus abutilifolia*, *Maytenus undata* (woodland form), *Mimusops zeyheri*, *Pterocarpus rotundifolius*, *Rhus leptodictya*, *Terminalia sericea*, *Vitex obovata* subsp. *wilmsii*. Succulent Tree: *Euphorbia cooperi*. Tall Shrubs: *Acalypha glabrata*, *Croton madandensis*, *Diospyros lycioides* subsp. *sericea*, *Grewia monticola*, *Olea europaea* subsp. *africana*, *Strychnos spinosa*. Low Shrubs: *Barleria rotundifolia*, *Orthosiphon labiatus*, *Polygala producta*. Succulent Shrub: *Aloe spicata*. Woody Climbers: *Bauhinia galpinii*, *Dalbergia armata*, *Pterolobium stellatum*. Woody Succulent Climber: *Senecio pleistocephalus*. Herbaceous Climbers: *Coccinia rehmannii*, *Rhynchosia caribaea*. Graminoids: *Bothriochloa radicans* (d), *Enneapogon scoparius* (d), *Eragrostis rigidior* (d), *Eustachys paspaloides*, *Heteropogon contortus*, *Themeda triandra*, *Tristachya leucothrix*, *Urochloa mosambicensis*. Geophytic Herb: *Drimia altissima*. Succulent Herb: *Plectranthus cylindraceus*. Epiphytic Succulent Herb: *Ansellia africana*. **High-lying open savanna:** Small Trees: *Acacia davyi* (d), *Combretum molle* (d), *Heteropyxis natalensis* (d), *Hippobromus pauciflorus* (d), *Sterculia murex* (d), *Acacia natalitia*, *Bersama lucens*, *Combretum kraussii*, *Cussonia spicata*, *Ekebergia capensis*, *Faurea rochetiana*, *Ficus ingens*, *Pavetta edentula*, *Rhus leptodictya*, *Vitex obovata* subsp. *wilmsii*. Tall Shrubs: *Olea capensis* subsp. *enervis* (d), *Canthium inerme*, *Rhus pentheri*, *Vernonia myriantha*. Low Shrubs: *Flemingia grahamiana* (d), *Helichrysum kraussii* (d), *Acalypha villicaulis*, *Asparagus virgatus*, *Diospyros galpinii*, *Helichrysum lepidissimum*, *Polygala producta*, *Tenrhynea phylicifolia*, *Vernonia crataegifolia*. Succulent Shrub: *Aloe spicata*. Woody Climber: *Dalbergia armata*. Graminoids: *Bothriochloa radicans* (d), *Enneapogon scoparius* (d), *Eragrostis rigidior* (d), *Andropogon eucomus*, *Eustachys paspaloides*, *Heteropogon contortus*, *Panicum natalense*, *Themeda triandra*, *Tristachya leucothrix*, *Urochloa mosambicensis*. Herbs: *Becium obovatum*, *Indigofera sanguinea*. Geophytic Herb: *Drimia altissima*. Succulent Herb: *Stapelia gigantea*. Epiphytic Succulent Herb: *Ansellia africana*.

Conservation Least threatened. Target 24%. About 39% statutorily conserved in the Kruger National Park and a further 6% conserved in the Mthethomusha Nature Reserve. At least 4% transformed, mainly by cultivation and urban and built-up areas. Scattered alien plants include *Lantana camara*, *Jacaranda mimosifolia*, *Melia azedarach*, *Solanum mauritianum*, *Sesbania punicea*, *Ricinus communis* and *Psidium guajava*. Erosion is generally very low to low.

Remarks This mountainous unit is similar to the SVl 9 Legogote Sour Bushveld, but which has a wetter and cooler climate. Two broad groups of plant communities are recognised, namely the high-lying open savannas and the low-lying closed savannas. The transition between these two community complexes is at an altitude of about 700 m.

Reference Gertenbach (1983b).

SVl 12 Kaalrug Mountain Bushveld

VT 10 Lowveld (73%) (Acocks 1953). LR 21 Sour Lowveld Bushveld (79%) (Low & Rebelo 1996).

Distribution Mpumalanga Province and slightly into Swaziland: Mountain slopes and hills from Barberton in the west continuing eastwards south of the Kaaps River and lower Crocodile River. Also including the lower slopes of Three Sisters and Kaalrug to the area of One Tree Hill and Wilson's Kop in the east. Altitude 350–950 m.

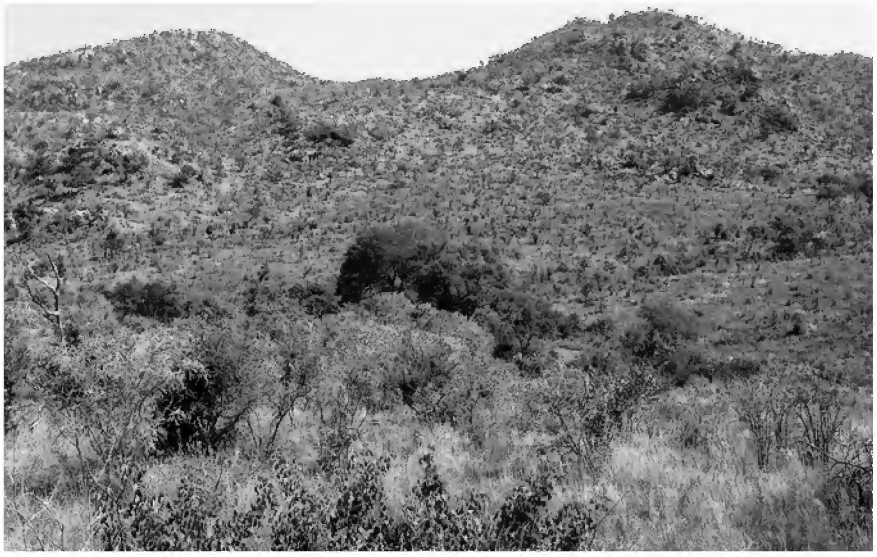

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Figure 9.53 SVl 11 Malelane Mountain Bushveld: General view of here moderately open bushveld near Berg-en-Dal Rest Camp, Kruger National Park.

Vegetation & Landscape Features Open to dense, short mountain savanna or thickets, with a more dense grassy layer at higher altitudes. Often steep or very broken mountain slopes at altitudes lower than the Gm 17 Barberton Montane Grassland.

Geology & Soils Rocky mountains of schists, gneiss, shale and quartzite of the Figtree, Moodies, and Onverwacht Groups of the Barberton Greenstone Belt. Also basaltic lava including the granodiorite of the Salisburykop Pluton. Soils shallow, mainly Glenrosa and Mispah forms, with some areas of vertic, melanic clays along lowest edges. Land types Fb, Fa and Ea.

Climate Summer rainfall with dry winters. MAP from about 650 mm on the footslopes of the mountains to about

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Figure 9.54 SVl 12 Kaalrug Mountain Bushveld. Rocky bushveld with *Olea europaea* subsp. *africana* and *Ficus sur* with some alien *Eucalyptus* species in the centre on Colombo Ranch mine east-northeast of Barberton.

1 200 mm where it borders grassland at higher altitudes. Frost infrequent to occasional at higher altitudes. See also climate diagram for SVl 12 Kaalrug Mountain Bushveld.

Important Taxa Small Trees: *Pavetta edentula* (d), *Sclerocroton integerrimum* (d), *Margaritaria discoidea*, *Tabernaemontana elegans*. Succulent Tree: *Euphorbia triangularis*. Tall Shrubs: *Combretum padoides* (d), *Diplorhynchus condylocarpon*, *Galpinia transvaalica*, *Maerua rosmarinoides*, *Monanthotaxis caffra, Olea europaea* subsp. *africana*. Low Shrubs: *Orthosiphon serratus*, *Pavetta gracilifolia*, *Ruttya ovata*. Succulent Shrub: *Euphorbia transvaalensis*. Soft Shrub: *Metarungia longistrobus*. Woody Climbers: *Combretum woodii* (d), *Caesalpinia rostrata*. Graminoids: *Bothriochloa radicans* (d), *Digitaria eriantha* subsp. *eriantha* (d), *Eragrostis rigidior* (d), *Eustachys paspaloides* (d), *Enneapogon scoparius*, *Heteropogon contortus*, *Panicum maximum*, *Schmidtia pappophoroides*, *Themeda triandra*. Herbs: *Senecio venosus*, *Vernonia natalensis*, *Waltheria indica*. Geophytic Herb: *Cyrtanthus galpinii*. Succulent Herb: *Plectranthus neochilus*.

Endemic Taxa Succulent Shrub: *Euphorbia complexa*. Geophytic Herb: *Ledebouria cremnophila*.

Conservation Least threatened. Target 24%. Some 16% statutorily conserved, almost all in Mountainlands Nature Reserve. A further 9% conserved in the private reserves of Cwantalala and Boondocks. About 12% transformed, mainly by cultivation and plantations. Erosion is generally very low.

Remarks This is a mesic mountain bushveld with some relationships to the mountain grassland, though woody species are most dominant. FOz 8 Scarp Forest patches occur in protected kloofs.

References Bredenkamp & Matthews (1991), De Frey (1999), Van Wyk & Smith (2001).

SVl 13 Barberton Serpentine Sourveld

VT 10 Lowveld (46%), VT 9 Lowveld Sour Bushveld (32%) (Acocks 1953). LR 21 Sour Lowveld Bushveld (86%) (Low & Rebelo 1996).

Distribution Mpumalanga Province: Occurs in fragmented patches on the exposed ultramafic substrates in a triangular region extending from Malelane in the east, to Badplaas, Barberton and eastern Swaziland in the south and to west of Nelspruit in the north. Altitude 350–1 400 m.

Vegetation & Landscape Features Often hilly, but very varied terrain. The southern ultramafic outcrops support herbaceous grasslands with stunted woody vegetation with more woody vegetation apparent within the lower-lying Noordkaap area and towards Malelane.

Geology & Soils Soils derived from ultramafic lavas (including komatiites and serpentinites), predominantly of the Onverwacht Group of the Barberton Supergroup (Barberton Greenstone Belt). The ultramafic geology gives rise to soils with unusually high magnesium: calcium ratios. These soils are associated with high concentrations of heavy metals such as Ni and Cr, which are generally toxic to most plants. Land types mostly Fa and Fb.

Climate Summer rainfall with dry winters. MAP about 600–1 150 mm. Frost infrequent. See also climate diagram for SVl 13 Barberton Serpentine Sourveld.

Important Taxa Small Trees: *Acacia caffra*, *A. davyi*, *Faurea rochetiana*, *Pavetta edentula*. Succulent Tree: *Aloe marlothii* subsp. *marlothii* (d). Tall Shrubs: *Erythroxylum delagoense*, *Tephrosia elongata*. Low Shrubs: *Gnidia caffra* (d), *G. sericocephala*, *Helichrysum kraussii*, *Jamesbrittenia grandiflora*, *Jatropha latifolia* var. *latifolia*, *Pearsonia sessilifolia*, *Rhus rogersii*, *Thunbergia atriplicifolia*. Herbaceous Climbers: *Rhynchosia minima*, *R. totta*. Graminoids: *Loudetia simplex* (d), *Themeda triandra* (d), *Andropogon schirensis*, *Bewsia biflora*, *Cymbopogon caesius*, *Diheteropogon amplectens*, *Eragrostis capensis*, *E. racemosa*, *Heteropogon contortus*, *Panicum natalense*. Herbs: *Helichrysum nudifolium* var. *pilosellum*, *Hemizygia persimilis*, *Rabdosiella calycina*, *Rhynchosia monophylla*, *Senecio coronatus*, *S. venosus*, *Vernonia natalensis*, *V. sutherlandii*. Geophytic Herb: *Cheilanthes involuta*.

Biogeographically Important Taxon (Link to Pondoland) Low Shrub: *Rhus pondoensis* (d).

Endemic Taxa Small Tree: *Protea curvata*. Low Shrubs: *Ozoroa barbertonensis*, *Rhus pygmaea*, *Sclerochiton triacanthus*. Succulent Shrub: *Aloe thorncroftii*. Herbs: *Berkheya coddii* (d), *B. zeyheri* subsp. *rehmannii* var. *rogersiana* (d), *Asystasia subbiflora*, *Berkheya nivea*, *Cyphia bolusii*, *Dicoma swazilandica*, *Inezia speciosa*. Geophytic Herbs: *Brachystelma dyeri*, *Gladiolus serpenticola*.

Conservation Vulnerable. Target 24%. Almost 6% statutorily conserved in the Songimvelo and Barberton Nature Reserves, amongst others. Almost 2% conserved in addition in private reserves including Queensriver and Boondocks. More than one quarter of the area has been transformed, mainly by plantations and cultivation.

Remarks Species richness on some serpentine sites is only slightly lower than that of surrounding areas, but on other serpentine sites the species richness is higher than that of the surrounding vegetation (S. Williamson, unpublished data). This higher species richness is probably due to the heterogeneous nature of these outcrops in terms of altitude, slope and soil conditions. In addition, this vegetation unit is very rich in endemics that have evolved as edaphic specialists. It has been suggested

that these plants could originally have colonised these areas with unfavourable soil conditions as a refuge from competition. There are 31 edaphic specialists known from this vegetation unit at present, of which 10 are still to be described.

References Morrey et al. (1989, 1992), Balkwill et al. (1997), Smith et al. (2001), S. Williamson (unpublished data).

SVl 14 Swaziland Sour Bushveld

VT 9 Lowveld Sour Bushveld (57%) (Acocks 1953). LR 43 North-eastern Mountain Grassland (73%) (Low & Rebelo 1996).

Distribution Mpumalanga Province, Swaziland and marginally into KwaZulu-Natal: From Badplaas, Tjakastad east to Piggs Peak area in the north, southwards through valleys around Manzini and slopes around the Grand Valley, and some isolated mountain outcrops in the lowveld plains, for example the Nkambeni Hills and Bulungu Mountains. Altitude 400–1 100 m.

Vegetation & Landscape Features Open to closed, medium to tall tree layer with closed well-developed grass layer. Very hilly with moderate to steep slopes, positioned at higher altitudes than the adjacent SVl 3 Granite Lowveld to the east.

Geology & Soils Grey soils derived mostly from Randian granites (Mpuluzi and Mswati) and Swazian granites and gneisses (Usutu Suite and Ngwane gneiss). The area reaches to the Onverwacht Group of the Barberton Greenstone Belt in the far north. Soils are dark, very clayey, of the Sterkspruit, Valsrivier, Swartland soil forms. Land types were unclassified in Swaziland, but elsewhere they are mainly Fa, Fb and Ae.

Climate Summer rainfall with dry winters. MAP about 700–1 350 mm. Frost infrequent to occasional at higher altitudes. See also climate diagram for SVl 14 Swaziland Sour Bushveld.

Important Taxa Tall Tree: *Philenoptera violacea*. Small Trees: *Acacia davyi* (d), *A. natalitia* (d), *A. sieberiana* var. *woodii* (d), *A. tortilis* subsp. *heteracantha* (d), *A. gerrardii, Combretum molle*, *C. zeyheri*, *Englerophytum magalismontanum*, *Faurea rochetiana*, *F. saligna*, *Pavetta edentula*, *Vangueria madagascariensis*, *Vitex obovata* subsp. *obovata*, *Ziziphus mucronata*. Succulent Tree: *Aloe marlothii* subsp. *marlothii*. Tall Shrubs: *Dichrostachys cinerea* (d), *Calpurnia glabrata*, *Cliffortia strobilifera*, *Crotalaria monteiroi*, *Elaeodendron transvaalense*, *Heteromorpha arborescens* var. *abyssinica*, *Rhus pallens*, *R. pentheri*, *Tricalysia lanceolata*. Low Shrubs: *Barleria obtusa*, *Crossandra fruticulosa*, *Gnidia splendens*, *Gymnosporia heterophylla*, *Jatropha latifolia* var. *angustata*, *J. latifolia* var. *swazica*, *Justicia flava*, *Passerina filiformis*, *Rhus grandidens*. Woody Climbers: *Helinus integrifolius*, *Putterlickia verrucosa*. Graminoids: *Panicum maximum* (d), *Themeda triandra* (d), *Enteropogon monostachyus*, *Sporobolus fimbriatus*, *S. nitens*. Herbs: *Becium obovatum*, *Gerbera viridifolia*, *Helichrysum miconiifolium*, *Hemizygia pretoriae* subsp. *pretoriae*, *Nidorella auriculata*. Geophytic Herbs: *Eulophia petersii*, *Hypoxis rigidula*.

Biogeographically Important Taxa ([KZN]Northern KwaZulu-Natal endemic, [N]Northern Sourveld endemic) Low Shrub: *Hemizygia gerrardii*[KZN]. Geophytic Herb: *Haemanthus pauculifolius*[N].

Endemic Taxa Geophytic Herbs: *Drimiopsis pusilla*, *D. reilleyana*.

Conservation Vulnerable. Target 19%. About 6% statutorily conserved in mainly the Songimvelo, Ithala and Malalotja Nature Reserves, and a further 0.5% conserved in the Mlilwane Game Sanctuary in Swaziland. Some 21% has been transformed by cultivation and plantations.

Remark In this savanna vegetation unit with the highest MAP, *Philenoptera violacea* is not as restricted to water courses in contrast to its generally close association with water course areas in the drier vegetation units of the Lowveld and Mopane Bioregions.

References Coetzee & Nel (1978), De Frey (1999), Stalmans et al. (1999), Stalmans (2002).

SVl 15 Northern Lebombo Bushveld

VT 11 Arid Lowveld (45%), VT 15 Mopani Veld (27%) (Acocks 1953). LR 13 Lebombo Arid Mountain Bushveld (56%) (Low & Rebelo 1996). KNP 29 Lebombo South (58%) (Gertenbach 1983b).

Distribution Mpumalanga and Limpopo Provinces: Lebombo Mountains south of the Shingwedzi River to the Komatipoort area, including ridge points such as Nhlanguleni. The mountain range forms a natural frontier between Mozambique and South Africa (Kruger National Park). Much of the eastern slopes are in Mozambique. Altitude 200–450 m.

Vegetation & Landscape Features Open bushveld dominated by Combretaceae on rocky slopes and ridges of a linear range of hills reaching about 100 m (and higher in places) above its surrounding basalt plains towards the west. Tree succulents such as *Euphorbia confinalis* and *E. cooperi* are typical on steep, stony slopes.

Geology & Soils Rhyolite of the Jozini Formation and lesser basalt of the Letaba Formation, both of the Lebombo Group (Karoo Supergroup) as well as dykes of granophyre (Jurassic) form ridges with stony, shallow lithosols with very frequent rocky outcrops. Soils are shallow (Mispah) as well as deeper (Swartland and Glenrosa). Land types Fb and Ea.

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Figure 9.55 SVl 14 Swaziland Sour Bushveld: Woodland with *Acacia gerrardii*, *A. karroo* and *Euclea schimperi* in Ithala Game Reserve, KwaZulu-Natal.

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Figure 9.56 SVl 15 Northern Lebombo Bushveld: Short savanna with *Lannea schweinfurthii* and *Combretum apiculatum* northeast of Letaba Rest Camp, Kruger National Park.

Conservation Least threatened. Target 24%. All statutorily conserved in the Kruger National Park and there has been virtually no transformation.

Remark There are *Androstachys johnsonii* 'thickets' embedded within this savanna unit (relate to the FOz 9 Ironwood Dry Forest further north).

References Van Rooyen (1978), Coetzee (1983), Gertenbach (1983b).

SVl 16 Southern Lebombo Bushveld

VT 10 Lowveld (62%) (Acocks 1953). LR 13 Lebombo Arid Mountain Bushveld (69%) (Low & Rebelo 1996).

Distribution Mpumalanga and KwaZulu-Natal Provinces and Swaziland: From Komatipoort, widening southwards into Swaziland, including the Mbuluzi River Gorge, through Siteki and across the Isuthu River Gorge into KwaZulu-Natal, extending east of Mkuze and terminating about 10 km north of Hluhluwe in the south. The high-altitude sourvelds are excluded and are SVl 17 Lebombo Summit Sourveld. Relatively small parts of this unit extend into Mozambique, mainly at the northern end. Altitude 100–600 m. Small patches are unmapped between the Mkuze and Msunduzi Rivers.

Climate Summer rainfall with dry winters. MAP about 350–750 mm. Incidence of fog in river gorges in the Lebombo Mountains supposedly contributes extensively to moisture availability to plants in these areas. Generally a frost-free area. Temperature on the western mountainside can become very high. See also climate diagram for SVl 15 Northern Lebombo Bushveld.

Important Taxa Tall Tree: *Sclerocarya birrea* subsp. *caffra*. Small Trees: *Combretum apiculatum* (d), *Acacia erubescens*, *A. exuvialis*, *Albizia harveyi*, *Boscia albitrunca*, *Combretum molle*, *Commiphora mollis*, *Croton gratissimus*, *Kirkia acuminata*, *Lannea schweinfurthii* var. *stuhlmannii*, *Manilkara mochisia*, *Newtonia hildebrandtii* var. *hildebrandtii*, *Ozoroa engleri*, *Pappea capensis*, *Sterculia rogersii*, *Strychnos decussata*, *Terminalia sericea*, *Ximenia caffra*. Succulent Trees: *Euphorbia confinalis* (d), *E. cooperi*. Tall Shrubs: *Dichrostachys cinerea* (d), *Croton madandensis*, *Flueggea virosa*, *Grewia bicolor*, *Karomia speciosa*. Low Shrubs: *Barleria affinis*, *Commiphora africana*, *Pavetta catophylla*, *Tragia dioica*, *Tricalysia junodii*. Succulent Shrubs: *Aloe chabaudii*, *A. spicata*, *Kalanchoe rotundifolia*. Woody Climbers: *Adenia digitata*, *A. spinosa*, *Capparis sepiaria*, *Cardiospermum halicacabum*, *Cissus rotundifolia*, *Helinus integrifolius*. Herbaceous Climber: *Cyphostemma subciliatum*. Graminoids: *Aristida congesta* (d), *Digitaria eriantha* subsp. *eriantha* (d), *Enneapogon cenchroides* (d), *Heteropogon contortus* (d), *Panicum maximum* (d), *Andropogon gayanus*, *Bothriochloa radicans*, *Brachiaria nigropedata*, *B. xantholeuca*, *Cymbosetaria sagittifolia*, *Panicum deustum*, *Pogonarthria squarrosa*, *Schmidtia pappophoroides*, *Themeda triandra*. Herbs: *Achyranthes aspera*, *Cleome maculata*, *Crabbea velutina*, *Heliotropium steudneri*. Geophytic Herbs: *Actiniopteris radiata*, *Pellaea calomelanos*, *P. viridis*, *Sansevieria pearsonii*.

Vegetation & Landscape Features Open bushveld with dominant *Acacia* and *Combretum* species. *Themeda triandra* is the dominant grass on undisturbed sites. On very shallow soils (e.g. slopes of deep gorges or exposed ridges) with *Aloe marlothii*, *Euphorbia confinalis* and thickets of *Olea europaea* subsp. *africana* and *Combretum woodii*. Dry slopes may be dominated by *Androstachys johnsonii* in the northern parts.

Geology & Soils Shallow lithosols developing over rhyolites of the Jozini Formation, Lebombo Group (Karoo). Soils shal-

L.W. Powrie

Figure 9.57 SVl 16 Southern Lebombo Bushveld: Dense bushveld with *Mundulea sericea*, *Dichrostachys cinerea* and *Peltophorum africanum* at an altitude of 355 m near Ubombo, northeast of Mkuze town, KwaZulu-Natal.

low Glenrosa and Mispah forms. Land types are unclassified in Swaziland and in South Africa the dominant land type is Fb.

Climate Summer rainfall with very little rain in winter. MAP about 550–1 000 mm. Frost very infrequent. See also climate diagram for SVl 16 Southern Lebombo Bushveld.

Important Taxa Tall Trees: *Acacia burkei* (Lebombo form), *A. nigrescens*. Small Trees: *Acacia davyi*, *A. gerrardii*, *Atalaya alata*, *Bridelia cathartica*, *Combretum apiculatum*, *C. molle*, *Commiphora harveyi*, *Croton gratissimus*, *Encephalartos lebomboensis*, *Erythroxylum emarginatum*, *Manilkara concolor*, *Peltophorum africanum, Pterocarpus rotundifolius*, *Strychnos gerrardii*, *Teclea gerrardii*, *Turraea floribunda*, *Vepris reflexa*, *Vitex obovata* subsp. *obovata*. Succulent Trees: *Euphorbia confinalis* (d), *Aloe marlothii* subsp. *marlothii*, *Euphorbia cooperi*, *E. tirucalli*. Tall Shrubs: *Diospyros dichrophylla* (d), *Cassipourea mossambicensis*, *Coptosperma supra-axillare*, *Dichrostachys cinerea, Euclea schimperi*, *Galpinia transvaalica*, *Hibiscus micranthus*, *Karomia speciosa*, *Maerua rosmarinoides*, *Olax dissitiflora*, *Olea europaea* subsp. *africana*, *Pouzolzia mixta*, *Rhus gueinzii*. Low Shrubs: *Barleria saxatilis*, *Jatropha variifolia*, *Mundulea sericea, Polygala producta*. Succulent Shrubs: *Aloe spicata* (d), *A. vanbalenii* (d), *A. chabaudii*, *Euphorbia knuthii* subsp. *knuthii*. Soft Shrub: *Metarungia longistrobus*. Woody Climbers: *Asparagus buchananii*, *Cissus quadrangularis*, *Combretum woodii*, *Pristimera longipetiolata*, *Sphedamnocarpus pruriens* subsp. *pruriens*. Herbaceous Climber: *Coccinia rehmannii*. Graminoids: *Brachiaria xantholeuca*, *Digitaria eriantha* subsp. *eriantha*, *Enneapogon cenchroides*, *Panicum deustum*, *P. maximum*, *Themeda triandra*, *Trachypogon spicatus*. Herbs: *Hibiscus meyeri* subsp. *meyeri*, *H. pedunculatus*, *Pupalia lappacea*. Geophytic Herbs: *Cheilanthes hirta*, *Gladiolus hollandii*, *Pellaea calomelanos*, *Sansevieria hyacinthoides*. Succulent Herbs: *Aloe parvibracteata, Stapelia unicornis*. Epiphytic Geophytic Herb: *Acampe pachyglossa*. Epiphytic Succulent Herb: *Ansellia africana*.

Biogeographically Important Taxa ([KZN]Northern KwaZulu-Natal endemic, [L]Lebombo endemic) Geophytic Herb: *Pachycarpus lebomboensis*[L]. Succulent Herb: *Gasteria batesiana* var. *batesiana*[KZN].

Endemic Taxa Small Trees: *Encephalartos aplanatus*, *E. senticosus*. Succulent Tree: *Euphorbia keithii*. Epiphytic Geophytic Herb: *Polystachya zuluensis*.

Conservation Least threatened. Target 24%. Some 10% statutorily conserved in the Mlawula Nature Reserve, Greater St Lucia Wetland Park, Mananga Cycad Colony as well as in the Ubombo Mountain and Phongolapoort Nature Reserves. A further 1% is conserved in the private Masibekela Wetland. About 9% of the area has been transformed, mainly by cultivation.

Remarks Some of the prehistory of mankind has been revealed in the Lebombo Mountains. The border cave is the site of one of the world's earliest records of *Homo sapiens* (100 000–200 000 BP). This unit is part of the Maputaland CE as defined by Van Wyk & Smith (2001).

References Moll (1978), Smith (2001), Van Wyk & Smith (2001).

SVl 17 Lebombo Summit Sourveld

VT 6 Zululand Thornveld (88%) (Acocks 1953). LR 13 Lebombo Arid Mountain Bushveld (85%) (Low & Rebelo 1996). BRG 15 Moist Lowland Tall Grassveld (83%) (Camp 1999c). Lebombo Grassland (Smith 2001).

Distribution KwaZulu-Natal Province with small parts in Mpumalanga Province and Swaziland: Localised high points on the crest of the Lebombo Mountains from Mbuzini (Mpumalanga) in the north to the Ubombo area immediately north of Mkuze River Gorge in the south. Also occurs in Mozambique in a very limited area north of Namaacha. Altitude mostly from above 600 to 803 m at the summit of Mananga Mountain.

Vegetation & Landscape Features Ridge plateaus and adjacent slightly sloping flanks covered with open, tall, sour, wiry grasslands, often dotted with low bushes and solitary savanna trees.

Geology & Soils Shallow soils of Glenrosa and Mispah forms over Jozini Formation rhyolite lavas (Karoo Supergroup). Heavier soils have developed over dolerite in places. Rocky outcrops are typical. Land types mainly Fa, Ea and Ib.

Climate Summer rainfall with little rain in winter. MAP about 600–1 050 mm. Generally frost-free. See also climate diagram for SVl 17 Lebombo Summit Sourveld.

Important Taxa Small Trees: *Acacia caffra*, *Encephalartos ngoyanus*. Tall Shrubs: *Diospyros dichrophylla*, *Gnidia caffra*, *Grewia monticola*. Low Shrubs: *Crossandra greenstockii*, *Diospyros galpinii*, *D. lycioides* subsp. *nitens*, *Phyllanthus glaucophyllus*, *Polygala producta*, *Ruellia cordata*, *Senecio medley-woodii*. Semiparasitic Shrub: *Thesium jeanae*. Graminoids: *Andropogon gayanus* (d), *Elionurus muticus* (d), *Heteropogon contortus* (d), *Themeda triandra* (d), *Brachiaria serrata*, *Cymbopogon caesius*, *Hyparrhenia filipendula*, *Hyperthelia dissoluta*, *Schizachyrium sanguineum*, *Tristachya leucothrix*. Herbs: *Argyrolobium adscendens*, *Berkheya insignis*, *Blepharis integrifolia*, *Crabbea hirsuta*, *Gazania krebsiana* subsp. *serrulata*, *Gerbera ambigua*, *Helichrysum nudifolium* var. *pilosellum*, *H. rugulosum*, *Indigofera sanguinea*, *Lepidagathis scabra*, *Vernonia oligocephala*, *Zornia capensis*. Succulent Herb: *Australluma ubomboensis*. Geophytic Herb: *Hypoxis hemerocallidea*.

Biogeographically Important Taxon (Lebombo endemic) Geophytic Herb: *Pachycarpus lebomboensis*.

Endemic Taxa Herb: *Cyphostemma barbosae*. Succulent Herb: *Orbea ubomboensis*.

Conservation One of the most endangered vegetation types in KwaZulu-Natal due to alien plant (*Lantana camara*) encroachment, heavy livestock grazing and expanding cultivation. Target 24%. About 4% is statutorily conserved in the Mananga Cycad Colony, Ubombo Mountain, Phongolapoort and Hlatikulu Nature Reserves. Very small portion also conserved in the private Masibekela Wetland Reserve. At least 41% already transformed, almost all by cultivation. Rural settlements are concentrated in these areas. Heavy utilisation and population density may have contributed to the open and less wooded aspect of this vegetation unit. Erosion is very low due to the hard substrate.

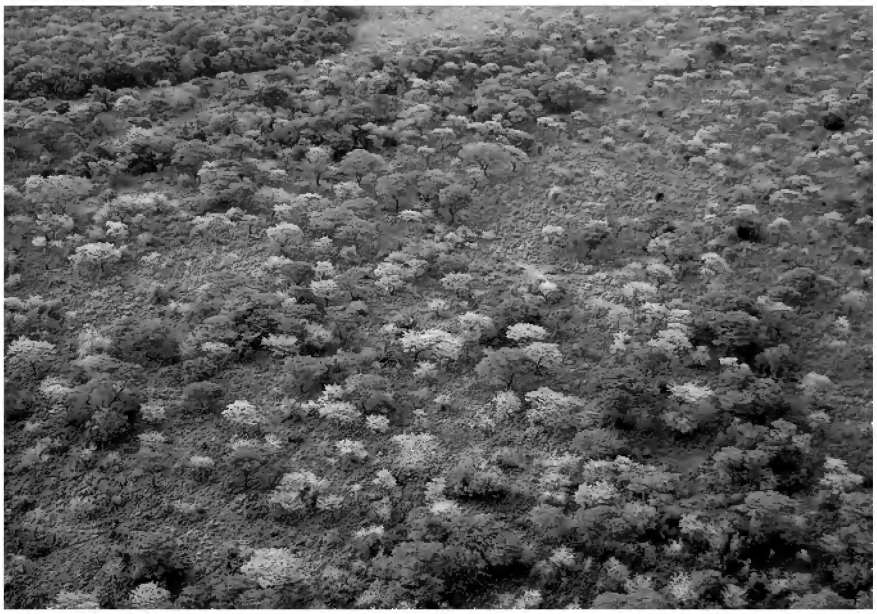
Remark Culturally important Gwaliweni Forest (classified as part of FOz 5 Scarp Forest) borders on this vegetation unit.

References Camp (1999c), Smith (2001), Van Wyk & Smith (2001).

SVl 18 Tembe Sandy Bushveld

VT 1 Coastal Forest and Thornveld (56%) (Acocks 1953). LR 22 Subhumid Lowveld Bushveld (77%) (Low & Rebelo 1996). BRG 23 Sandy Bush & Palm Veld (99%) (Camp 1999e).

Distribution KwaZulu-Natal Province: Part of the Maputaland lowveld, east of the Pongola River. Strip of land between the Mozambique border and the Tembe Elephant Park in the north extending south as far as the surrounds of the confluence of



W.S. Matthews

Figure 9.58 SVl 18 Tembe Sandy Bushveld: An aerial view of the *Terminalia sericea*-dominated sandy bushveld in Tembe Elephant Park in Maputaland.

the Mkuze and Msunduzi Rivers. Sandwiched between the SVl 20 Western Maputaland Clay Bushveld in the west and CB 1 Maputaland Coastal Belt in the east. Isolated patch found east of the town of Hluhluwe. Altitude 40–140 m.

Vegetation & Landscape Features Extensive flat plains to slightly undulating in places with open to closed woodland with canopy 5–10 m tall, dominated by leguminous woody species and *Terminalia sericea*, with species-rich shrub layer and grassy undergrowth (*Panicum*, *Perotis*, *Urelytrum agropyroides*, *Hyperthelia dissoluta* and *Diheteropogon* species).

Geology & Soils System of old (5–3 million years) and younger (125 000 years) grey regic to reddish redistributed sand dunes of marine origin. Nutritionally the sandy soils are very poor and well leached. In some depressions, duplex soils can be found. Land type mainly Ha, with some Ae, Ah and Hb also occurring.

Climate Summer rainfall with some rain in winter. MAP about 550–800 mm. Mist of the warm Indian Ocean contributes to precipitation. No incidence of frost. See also climate diagram for SVl 18 Tembe Sandy Bushveld.

Important Taxa Tall Trees: *Acacia burkei*, *Sclerocarya birrea* subsp. *caffra*. Small Trees: *Terminalia sericea* (d), *Afzelia quanzensis*, *Albizia adianthifolia*, *A. versicolor*, *Clausena anisata*, *Combretum molle*, *Diospyros inhacaensis*, *Ozoroa engleri*, *O. obovata* var. *elliptica*, *Spirostachys africana*, *Tabernaemontana elegans*, *Vepris lanceolata*, *Zanthoxylum capense*. Tall Shrubs: *Strychnos madagascariensis* (d), *Coddia rudis*, *Crotalaria monteiroi*, *Dichrostachys cinerea*, *Euclea natalensis*, *Gardenia volkensii*, *Grewia caffra*, *Monanthotaxis caffra*, *Rhus gueinzii*, *Strychnos spinosa*. Low Shrubs: *Corchorus junodii*, *Indigofera inhambanensis*. Woody Climber: *Landolphia kirkii*. Herbaceous Climber: *Cissampelos hirta*. Graminoids: *Panicum maximum* (d), *Aristida stipitata* subsp. *graciliflora*, *Digitaria eriantha* subsp. *eriantha*, *Diheteropogon amplectens*, *Eragrostis moggii*, *Hyperthelia dissoluta*, *Perotis patens*, *Pogonarthria squarrosa*, *Urelytrum agropyroides*. Herb: *Oxygonum delagoense*. Succulent Herb: *Aloe parvibracteata*. Semiparasitic Herb: *Striga junodii*.

Biogeographically Important Taxa (Maputaland endemics) Small Tree: *Dialium schlechteri*. Tall Shrubs: *Cussonia arenicola*, *Lagynias monteiroi*, *Synaptolepis kirkii*, *Tarenna junodii*. Low Shrub: *Rhus kwazuluana*. Succulent Shrub: *Aloe marlothii* subsp. *orientalis*. Woody Climbers: *Acridocarpus natalitius* var. *linearifolius*, *Albertisia delagoensis*, *Prionostemma delagoensis* var. *delagoensis*. Herbs: *Aneilema arenicola*, *Pelargonium tongaense*. Geophytic Herbs: *Aspidoglossum delagoense*, *Crinum acaule*. Succulent Herb: *Crassula maputensis*.

Endemic Taxa Low Shrub: *Pavetta vanwykiana*. Herb: *Cleome bororensis*.

Conservation Least threatened. Target 19%. Some 17% statutorily conserved, almost all in the Tembe Elephant Park. The Manqakulane people have established the Tshanini Game Reserve south of Tembe. About 8% has been transformed mainly by cultivation. Erosion is very low.

Remarks The origin of the name relates to the Tembe people living in the area and the Tembe Elephant Park located in the north of this unit in South Africa. The unit extends to the Maputaland part of southern Mozambique. This bushveld unit surrounds most of the Licuati Sand Forests (see Von Maltitz et al. 2003).

References Moll (1978), Camp (1999e), Matthews et al. (2001), Gaugris et al. (2004).

SVl 19 Western Maputaland Sandy Bushveld

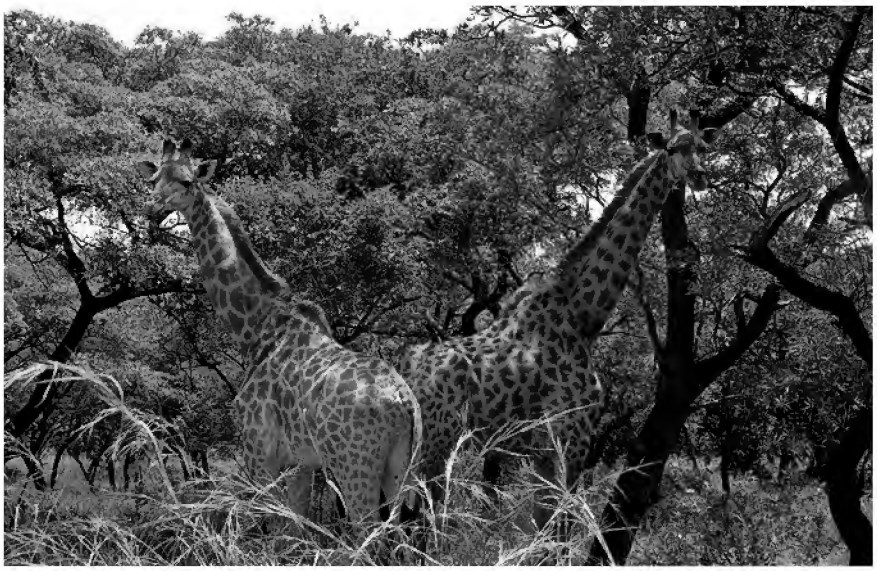
VT 10 Lowveld (90%) (Acocks 1953). Red Sand Bushveld (Moll 1980). LR 26 Natal Lowveld Bushveld (99%) (Low & Rebelo 1996). BRG 22 Lowveld (85%) (Camp 1999e).

Distribution KwaZulu-Natal Province: Isolated patches on the coastal plain in the Maputaland region east of the Lebombo Mountains from the Ndumo Game Reserve on the Mozambique border in the north to the Mkhuze Game Reserve (now part of Greater St Lucia Wetland Park) in the south. Altitude 40–180 m.

Vegetation & Landscape Features Comprised of mixed, but mainly simple-leaved, short (5–10 m) bushlands, woodlands and wooded grasslands. Occurring on the mid- and lower midslopes of ancient coastal dune cordons on gently undulating terrain. Extreme variations include open-canopy *Terminalia sericea* sandveld on deeper yellow to orange sands, through to *Combretum molle*-dominated woodlands on the deep red mesotrophic sands.

Geology & Soils Underlying geology comprises the innermost (most westerly) carbonate-rich sandy dune cordon and siltstones formed in the shallow marine and near-coastal environment of the Cenozoic Maputaland and the Mesozoic Zululand Groups. This cordon is poorly preserved with generally well-developed soil profiles which are commonly red to orange. Soils comprise ferruginous arenosols of the Clovelly and Hutton forms. These are well-drained mesotrophic soils with a low clay content (5–14%). Land types typically Ae and Ah.

Climate Summer rainfall with dry winters. MAP about 500–700 mm. Mean daily maximum and minimum temperatures for Mkhuze Game Reserve 32.5°C and 11.7°C for January and July, respectively. Mean monthly maximum and minimum temperatures for Ndumo Game Reserve 40.1°C and 6.2°C for January



P.C. Rutherford

Figure 9.59 SVl 19 Western Maputaland Sandy Bushveld: Moderately dense savanna dominated by *Terminalia sericea* on a sandy slope in Ndumo Game Reserve, KwaZulu-Natal.

Distribution KwaZulu-Natal Province: Maputaland region immediately east of the Lebombo Mountains, eastwards to the western edge of the SVl 18 Tembe Sandy Bushveld. From the Ndumo Game Reserve on the Mozambique border, through the Makatini Flats south to Mkhuze Game Reserve, with a narrower extension to just east of the town Hluhluwe. Altitude 20–200 m.

Vegetation & Landscape Features Comprises a mixed but mainly compound leaved short (5–10 m) woodlands and wooded grasslands. It occurs on the crests, upper and midslopes of gently undulating terrain. This vegetation unit is dissected by two large alluvial floodplains associated with the Mkuze and Phongolo Rivers. FOa 1 Lowveld Riverine Forest and woodland dominate these alluvial soils and numerous small floodplains associated with smaller streams.

and July, respectively. Mean annual evaporation (A-pan) 2 100 mm for Mkhuze Game Reserve. No incidence of frost. See also climate diagram for SVl 19 Western Maputaland Sandy Bushveld.

Important Taxa Tall Tree: *Acacia burkei*. Small Trees: *Combretum molle* (d), *Terminalia sericea* (d), *Balanites maughamii*, *Bolusanthus speciosus*, *Boscia albitrunca*, *Commiphora neglecta*, *Ziziphus mucronata*. Tall Shrubs: *Brachylaena discolor*, *Carissa tetramera*, *Catunaregam obovata*, *Euclea natalensis*, *Gardenia volkensii*, *Grewia bicolor*, *G. caffra*, *Mundulea sericea*, *Pteleopsis myrtifolia*, *Rhus gueinzii*, *Strychnos madagascariensis*, *S. spinosa*, *Vitex ferruginea*. Low Shrubs: *Helichrysum athrixiifolium*, *Melhania forbesii*, *Solanum panduriforme*. Graminoids: *Dactyloctenium australe* (d), *Sporobolus fimbriatus* (d), *Aristida congesta*, *Eragrostis ciliaris*, *E. pallens*, *Panicum maximum*, *Perotis patens*, *Tragus berteronianus*. Geophytic Herb: *Drimia altissima*.

Biogeographically Important Taxa (Maputaland endemics) Tall Shrub: *Tarenna junodii*. Woody Climber: *Acridocarpus natalitius* var. *linearifolius*. Herb: *Helichrysopsis septentrionale*.

Endemic Taxon Succulent Herb: *Plectranthus psammophilus*.

Conservation Least threatened. Target 19%. Some 18% statutorily conserved, mainly in the Greater St Lucia Wetland Park (Mkhuze) and Ndumo Game Reserve. Very little (2%) transformed, mainly by cultivation. Erosion is low to moderate.

Remark The sandy patches of this unit are usually elevated above much of the surrounding clay flats.

References De Moor et al. (1977), Moll (1978), Goodman (1990), Camp (1999e).

SVl 20 Western Maputaland Clay Bushveld

VT 10 Lowveld (75%) (Acocks 1953). Mixed Bushveld p.p. (Moll 1978). LR 26 Natal Lowveld Bushveld (74%) (Low & Rebelo 1996). BRG 22 Lowveld (88%) (Camp 1999e).

Geology & Soils Underlying geology comprises Cretaceous shallow-marine and coastal sediments, siltstones and conglomerates of the Zululand Group and minor rhyolites of the Jozini Formation (Karoo Supergroup). Dominant or zonal soils of this vegetation unit are latosols comprising red sandy clay loam to red clay soils (Hutton, Bainsvlei and Shortlands soil forms) and nonduplex brown calcimorphic soils comprising yellow-brown sandy clay, sandy loam to sandy clay loams (Valsrivier and Avalon soil forms). These are generally fertile soils, characterised by a moderate to high clay content (20–60%) in the A-horizon. Land types Ea, Ae, Dc, Ia and Db.

Climate Rainfall occurs in summer with dry winters. MAP about 500–750 mm. No incidence of frost. Mean monthly maximum and minimum temperatures for Makatini-Agr 39.5°C and 3.1°C for January and July, respectively. See also climate diagram for SVl 20 Western Maputaland Clay Bushveld.

Important Taxa Tall Tree: *Acacia nigrescens* (d). Small Trees: *Acacia nilotica* (d), *A. tortilis* subsp. *heteracantha* (d), *Bolusanthus speciosus* (d), *Acacia gerrardii*, *A. grandicornuta*, *A. luederitzii* var. *retinens*, *A. senegal* var. *rostrata*, *Spirostachys africana*, *Ziziphus mucronata*. Tall Shrubs: *Dichrostachys cinerea*

L. Mucina

Figure 9.60 SVl 20 Western Maputaland Clay Bushveld: Typical umbrella thorn (*Acacia tortilis*) in open savanna in the Mkhuze Game Reserve portion of the Greater St Lucia Wetland Park.

(d), *Gymnosporia senegalensis* (d), *Azima tetracantha*, *Cadaba natalensis*, *Carissa bispinosa* subsp. *bispinosa*, *C. tetramera*, *Ehretia rigida* subsp. *rigida*, *Euclea divinorum*, *Galpinia transvaalica*, *Grewia caffra*, *Salvadora angustifolia*. Low Shrubs: *Abutilon austro-africanum*, *Dicliptera clinopodia*, *Maerua edulis*. Graminoids: *Bothriochloa insculpta* (d), *Dactyloctenium australe* (d), *Panicum maximum* (d), *Themeda triandra* (d), *Aristida congesta*, *Digitaria didactyla*, *D. eriantha* subsp. *eriantha*, *Eragrostis rigidior*, *E. superba*, *Panicum coloratum*, *Sehima galpinii*, *Sporobolus fimbriatus*, *S. nitens*, *Urochloa mosambicensis*. Herbs: *Asystasia gangetica*, *Chascanum hederaceum*, *Crossandra greenstockii*, *Hibiscus pusillus*.

Conservation Vulnerable. Target 19%. About 11% statutorily conserved in the Greater St Lucia Wetland Park (Mkhuze) and Ndumo Game Reserve. A significant proportion (34%) has been transformed—almost all by cultivation. Alien plant infestations are locally severe and include *Opuntia* species.

References De Moor et al. (1977), Moll (1978), Goodman (1990), Camp (1999e).

SVl 21 Makatini Clay Thicket

VT 10 Lowveld (63%) (Acocks 1953). LR 26 Natal Lowveld Bushveld (95%) (Low & Rebelo 1996). BRG 22 Lowveld (92%) (Camp 1999e).

Distribution KwaZulu-Natal Province: A number of patches in the Maputaland region, primarily east of the Lebombo Mountains, from Ndumo Game Reserve on the Mozambique border through the Makatini Flats south to just east of the town Hluhluwe. Mostly embedded as varying sized patches within the SVl 20 Western Maputaland Clay Bushveld, where it occurs in bottomland positions. Small unmapped fragments of Makatini Clay Thicket occur west of the Lebombo Mountains, embedded within the SVl 23 Zululand Lowveld. Altitude 40–140 m.

Vegetation & Landscape Features Comprises a mixed, but mainly simple-leaved short bushland and thicket with emergent trees up to 10 m and a generally dense dominant shrub layer 1–4 m tall. It occurs on the lower slopes and bottomland areas of gently undulating terrain. Small clay-bottom, endorheic pans occur commonly at low points in the terrain.

Geology & Soils Underlying geology comprises mostly Cretaceous sandstones, siltstones and conglomerates of the Zululand Group (Mzinene and Makatini Formations). Dominant soils are vertic or melanic clays and clay loams of the Rensburg, Arcadia and Bonheim forms. They are characterised by being poorly drained, with calcium carbonate concretions on the surface or in the A-horizon. Land types mainly Ea and Dc with some Ae and Db.

Climate Rainfall occurs in summer with dry winters. MAP about 500–750 mm. No incidence of frost. See also climate diagram for SVl 21 Makatini Clay Thicket.

Important Taxa Small Trees: *Acacia luederitzii* var. *retinens* (d), *A. grandicornuta*, *A. nilotica*, *Albizia anthelmintica*, *Berchemia zeyheri*, *Ozoroa engleri*, *Schotia capitata*, *Sideroxylon inerme*, *Spirostachys africana*. Tall Shrubs: *Euclea divinorum* (d), *Croton menyharthii*, *Ehretia rigida* subsp. *rigida*, *Erythroxylum delagoense*, *Euclea schimperi*, *Lycium acutifolium*, *Rhus gueinzii*. Low Shrubs: *Barleria elegans*, *Ecbolium glabratum*, *Solanum capense*. Succulent Shrub: *Euphorbia grandicornis*. Graminoids: *Bothriochloa insculpta*, *Chloris mossambicensis*, *Dactyloctenium australe*, *Enteropogon monostachyus*, *Panicum deustum*, *P. maximum*, *Sporobolus nitens*. Herbs: *Blepharis integrifolia*, *Centema subfusca*. Succulent Herb: *Orbea paradoxa*.

Endemic Taxon Geophytic Herb: *Raphionacme elsana*.

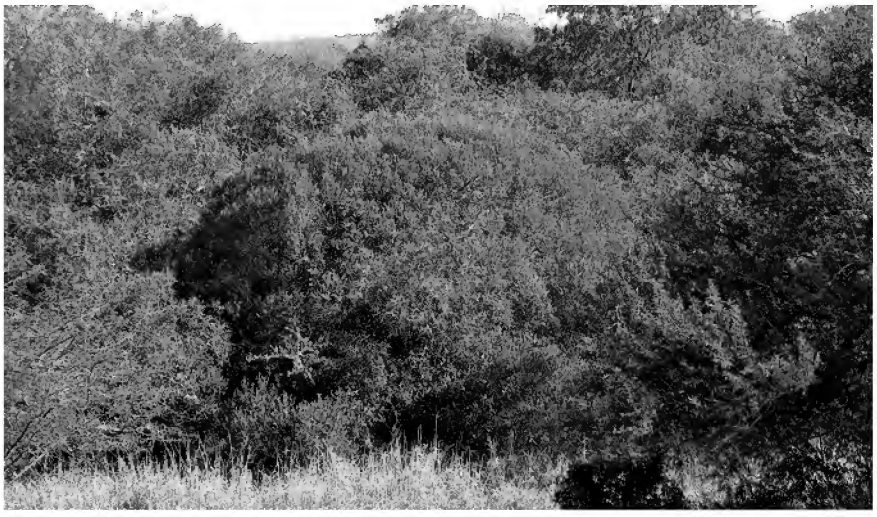
Conservation Least threatened. Target 19%. Some 42% statutorily conserved in the Greater St Lucia Wetland Park (Mkhuze) and Ndumo Game Reserve. About 7% already transformed, mainly by cultivation.

References De Moor et al. (1977), Moll (1978), Goodman (1990), Camp (1999e).

SVl 22 Northern Zululand Sourveld

VT 10 Lowveld (31%), VT 6 Zululand Thornveld (24%) (Acocks 1953). LR 26 Natal Lowveld Bushveld (32%), LR 25 Natal Central Bushveld (24%) (Low & Rebelo 1996). BRG 20 Dry Zululand Thornveld (34%), BRG 16 Dry Lowland Tall Grassveld (29%) (Camp 1999c).

Distribution KwaZulu-Natal Province and Swaziland: From the Lusthof area in Swaziland southwards with scattered patches in northern Zululand in the surrounds of Hlomohlomo, east of Louwsburg, Nongoma and the vicinity of Ulundi including Nkandla. In the Hluhluwe-iMfolozi Park it occurs at highest altitudes in the park. Altitude mainly 450–900 m.



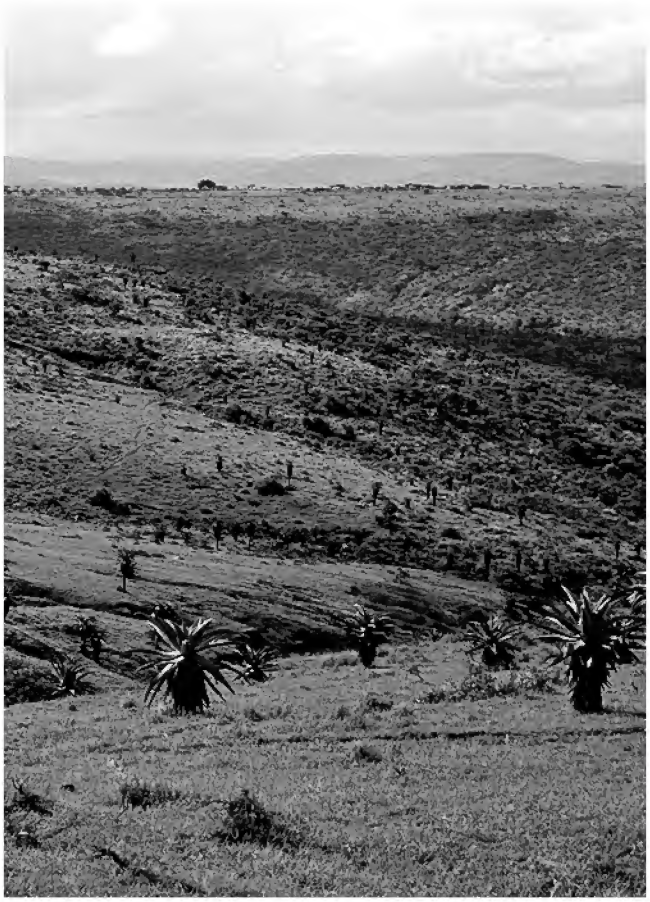
P.S. Goodman

Figure 9.61 SVl 21 Makatini Clay Thicket: *Acacia luederitzii* var. *retinens* – *Euclea divinorum* Thicket with emergent *Berchemia zeyheri* on melanic bottomland clay soils of the Makatini Flats, southern Maputaland, KwaZulu-Natal.

Vegetation & Landscape Features The dominant structural vegetation type is wooded grassland, in places pure sour grasslands and rarely also dense bushveld thickets. Terrain is mainly low, undulating mountains, sometimes highly dissected, and also some moderately undulating plains and hills.

Geology & Soils Well-drained and shallow soil forms (Glenrosa and Mispah forms) derived from various lithologies; predominantly, Dwyka Group diamictites, but also shale, siltstone and sandstone from the Madzaringwe and Pietermaritzburg Formations, all of the Karoo Supergroup. Archaean granite and gneiss are also significant. Land types mainly Fb and Fa, with some Ac.

Climate Summer rainfall with a little rain in winter. MAP about 600–1 050 mm



L.W. Powrie

Figure 9.62 SVl 22 Northern Zululand Sourveld: Heavily utilised communal farming area north of Nongoma, KwaZulu-Natal.

reaching a maximum, for example, in the region northwest of Nongoma, towards the mistbelt Ngome Forest. Frost very infrequent to occasional. See also climate diagram for SVl 22 Northern Zululand Sourveld.

Important Taxa Small Trees: *Acacia sieberiana* var. *woodii* (d), *A. natalitia*, *A. nilotica*, *A. tortilis* subsp. *heteracantha*, *Plectroniella armata*. Tall Shrubs: *Gardenia volkensii*, *Gnidia caffra*, *G. kraussiana*. Low Shrubs: *Agathisanthemum bojeri*, *Chaetacanthus burchellii*, *Crossandra fruticulosa*, *C. greenstockii*, *Diospyros galpinii*, *Phyllanthus glaucophyllus*, *Ruellia cordata*, *Syncolostemon argenteus*, *Tetraselago natalensis*. Succulent Shrub: *Aloe vanbalenii*. Woody Climber: *Cryptolepis oblongifolia*. Herbaceous Climber: *Cyphostemma schlechteri*. Graminoids: *Eragrostis curvula* (d), *Hyparrhenia hirta* (d), *Microchloa caffra* (d), *Themeda triandra* (d), *Tristachya leucothrix* (d), *Alloteropsis semialata* subsp. *semialata*, *Digitaria argyrograpta*, *D. tricholaenoides*, *Diheteropogon amplectens*, *Elionurus muticus*, *Loudetia simplex*, *Trachypogon spicatus*. Herbs: *Alepidea longifolia*, *Argyrolobium adscendens*, *Aster bakerianus*, *Berkheya speciosa*, *Chascanum hederaceum*, *Crabbea hirsuta*, *Gazania krebsiana* subsp. *serrulata*, *Gerbera ambigua*, *Helichrysum mixtum*, *H. nudifolium* var. *pilosellum*, *Hemizygia pretoriae* subsp. *pretoriae*, *Hermannia grandistipula*, *Hypericum aethiopicum*, *Lichtensteinia interrupta*, *Pimpinella caffra*, *Senecio glaberrimus*, *S. latifolius*, *Stachys nigricans*, *Vernonia galpinii*, *V. oligocephala*. Geophytic Herbs: *Hypoxis hemerocallidea*, *Pachycarpus concolor*. Succulent Herbs: *Aloe minima*, *A. parvibracteata*, *Senecio oxyriifolius*. Geoxylic Suffrutex: *Salacia kraussii*.

Conservation Vulnerable. Target 19%. Only 4% statutorily conserved, mainly in the Hluhluwe-iMfolozi Park and Ithala Game Reserve. Some 22% already transformed, mainly by cultivation and plantations. Erosion is generally moderate to high.

Remark Northern Zululand Sourveld can be seen as a northern extension of the SVs 4 Ngongoni Veld.

Reference Camp (1999c).

SVl 23 Zululand Lowveld

VT 10 Lowveld (71%) (Acocks 1953). LR 26 Natal Lowveld Bushveld (49%), LR 20 Sweet Lowveld Bushveld (12%) (Low & Rebelo 1996). BRG 22 Lowveld (63%) (Camp 1999e).

Distribution KwaZulu-Natal Province, Swaziland and Mpumalanga Province: Main extent from around Big Bend south to Mkuze, Hluhluwe, Ulundi to just north of the Ongoye Forest. An isolated patch is found on the Swaziland–Mpumalanga border. Altitude about 50–450 m.

Vegetation & Landscape Features Extensive flat or only slightly undulating landscapes supporting complex of various bushveld units ranging from dense thickets of *Dichrostachys cinerea* and *Acacia* species, through park-like savanna with flat-topped *A. tortilis* to tree-dominated woodland with broad-leaved open bushveld with *Sclerocarya birrea* subsp. *caffra* and *A. nigrescens*. Tall grassveld types with sparsely scattered solitary trees and shrubs form a mosaic with the typical savanna thornveld, bushveld and thicket patches.

Geology & Soils Black-clay soils and duplex soils derived from a distinct variety of clastic sediments of the Dwyka, Ecca, Beaufort and igneous rocks of the Lebombo Groups (all of the Karoo Supergroup). Also well-drained soil forms occur especially on stony slopes. Land types Fb and Ea, with some Db and Dc.

L. Mucina

Figure 9.63 SVl 23 Zululand Lowveld: Extensive areas covered by bushveld of this unit at lower altitudes and with SVl 22 Northern Zululand Sourveld visible at higher altitudes in the Hluhluwe-iMfolozi Game Park (Hluhluwe section) in KwaZulu-Natal. Patches of FOz 5 Scarp Forest are visible in the sub-summit positions of the ridges in the background.

Climate Summer rainfall with some rain in winter. MAP about 500–900 mm (highest in the southeast). Generally a frost-free area. Mean monthly maximum and minimum temperatures for Mpila Camp (Hluhluwe-iMfolozi Park) 38.5°C and 7.8°C for February and June, respectively. See also climate diagram for SVl 23 Zululand Lowveld.

Important Taxa Tall Trees: *Acacia burkei* (d), *A. nigrescens* (d), *Sclerocarya birrea* subsp. *caffra* (d). Small Trees: *Acacia tortilis* subsp. *heteracantha* (d), *A. gerrardii*, *A. natalitia*, *A. nilotica*, *A. senegal* var. *rostrata*, *A. welwitschii* subsp. *welwitschii*, *Boscia albitrunca*, *Combretum apiculatum*, *C. molle*, *Ozoroa paniculosa*, *Phoenix reclinata*, *Schotia brachypetala*, *Spirostachys africana*, *Teclea gerrardii*, *Ziziphus mucronata*. Succulent Trees: *Aloe marlothii* subsp. *marlothii*, *Euphorbia grandidens*, *E. ingens*. Tall Shrubs: *Dichrostachys cinerea* (d), *Euclea divinorum* (d), *Coptosperma supra-axillare*, *Crotalaria monteiroi*, *Euclea crispa* subsp. *crispa*, *E. schimperi*, *Galpinia transvaalica*, *Gardenia volkensii*, *Gymnosporia maranguensis*, *G. senegalensis*, *Jatropha zeyheri*, *Lycium acutifolium*, *Olea europaea* subsp. *africana*, *Tarchonanthus parvicapitulatus*, *Tephrosia polystachya*, *Triumfetta pilosa* var. *tomentosa*. Low Shrubs: *Barleria obtusa*, *Crossandra greenstockii*, *Felicia muricata*, *Gymnosporia heterophylla*, *Indigofera trita* subsp. *subulata*, *Justicia flava*, *J. protracta* subsp. *protracta*, *Melhania didyma*, *Orthosiphon serratus*, *Pearsonia sessilifolia*, *Ruellia cordata*, *Sida serratifolia*, *Tetraselago natalensis*. Succulent Shrubs: *Euphorbia grandicornis, E. trichadenia*, *E. vandermerwei*. Soft Shrub: *Pavonia columella*. Herbaceous Climber: *Fockea angustifolia*. Graminoids: *Dactyloctenium australe* (d), *Enteropogon monostachyus* (d), *Eragrostis capensis* (d), *E. curvula* (d), *E. racemosa* (d), *Heteropogon contortus* (d), *Panicum maximum* (d), *Sporobolus pyramidalis* (d), *Themeda triandra* (d), *Aristida bipartita*, *A. congesta*, *Bothriochloa insculpta*, *Chloris mossambicensis*, *Cymbopogon caesius*, *Digitaria natalensis*, *Leptochloa eleusine*, *Panicum deustum*, *Schizachyrium sanguineum*, *Setaria incrassata*, *Sporobolus nitens*, *Trachypogon spicatus*, *Tristachya leucothrix*. Herbs: *Acrotome hispida*, *Argyrolobium rupestre*, *Aspilia mossambicensis*, *Chamaecrista biensis*, *C. mimosoides*, *Corchorus asplenifolius*, *Felicia mossamedensis*, *Gerbera ambigua*, *Helichrysum rugulosum*, *Hibiscus pusillus*, *Kohautia virgata*, *Lotononis eriantha*, *Senecio latifolius*, *Stachys aethiopica*, *Tragia meyeriana*, *Vernonia capensis*. Succulent Herb: *Aloe parvibracteata*.

Biogeographically Important Taxa Small Tree: *Acacia theronii* (Broadly disjunct distribution). Tall Shrub: *Lycium shawii* (Southern distribution limit).

Conservation Vulnerable. Target 19%. Some 11% statutorily conserved mainly in the Hluhluwe-iMfolozi Park and Phongolapoort Nature Reserve. Almost 1% is protected in the private Masibekela Wetland. Much of the area between Magudu, Mkuze and Nongoma is managed as private game farms and lodges. About 26% of the area has been transformed, mostly by cultivation. Erosion is variable from low to high.

Remark Most of the Hluhluwe-iMfolozi Park is covered by tall grassveld and thornveld of this vegetation unit.

References Ward (1962), Downing (1972, 1980), Macdonald (1980, 1981), Watson & Macdonald (1983), Whateley & Porter (1983), Camp (1999e).

SVl 24 Zululand Coastal Thornveld

VT 1 Coastal Forest and Thornveld (71%) (Acocks 1953). LR 23 Coastal Bushveld-Grassland (94%) (Low & Rebelo 1996). BRG 1 Moist Coast Forest Thorn & Palm Veld (100%) (Camp 1999a).

Distribution KwaZulu-Natal Province: Immediately west of Mtubatuba (in the north) and Empangeni (in the south) bisected by the iMfolozi River, extending westwards for 10–20 km. Altitude 40–300 m.

Vegetation & Landscape Features Gently rolling landscapes supporting wooded grassland dominated by *Themeda triandra*. The bush clumps are a strong feature and are more numerous on deeper soils, with *Phoenix reclinata* and *Gymnosporia senegalensis* usually dominant. These plant communities are species-rich relative to the surrounding vegetation units. They grade into dense *Acacia* woodland on dry slopes and riverine bushland thickets and FOa 1 Lowveld Riverine Forest in valley bottoms.

Geology & Soils The area is situated almost entirely on Letaba Formation basalts of the Karoo Supergroup. Soils are mainly black with a high (35–55%) clay content and depth in the range 200–300 mm. Land types mainly Ea with some Fb and Dc.

Climate Summer rainfall but also some in winter (each winter month receiving about 20 mm, which is greater than that of any of the other savanna vegetation units for this period). MAP about 800–1 050 mm, generally higher towards the coast. Frost very infrequent. See also climate diagram for SVl 24 Zululand Coastal Thornveld.

Important Taxa Small Trees: *Acacia natalitia*, *A. nilotica*, *Phoenix reclinata*. Succulent Trees: *Euphorbia tirucalli* (d), *E. ingens*. Tall Shrubs: *Diospyros lycioides* subsp. *sericea* (d), *Euclea divinorum* (d), *Gymnosporia senegalensis* (d), *Abutilon angulatum*, *Clutia abyssinica*, *Euclea schimperi*, *Gymnosporia buxifolia*. Low Shrubs: *Acalypha peduncularis*, *Clutia cordata*, *Sida cordifolia*, *S. dregei*, *Thunbergia atriplicifolia*. Herbaceous Climbers: *Rhynchosia minima*, *R. totta*. Graminoids: *Eragrostis capensis* (d), *Panicum maximum* (d), *Sporobolus pyramidalis* (d), *Themeda triandra* (d), *Tristachya leucothrix* (d), *Aristida congesta*, *Eragrostis curvula*, *E. racemosa*, *Heteropogon contortus*, *Hyparrhenia hirta*, *Schizachyrium sanguineum*, *Setaria sphacelata*, *Trachypogon spicatus*. Herbs: *Berkheya setifera*, *B. speciosa*, *Centella asiatica*, *Eriosema cordatum*, *E. distinctum*, *Gerbera viridifolia*, *Helichrysum nudifolium* var. *pilosellum*, *Hypericum aethiopicum*, *Indigofera hilaris*, *I. sanguinea*, *Pentanisia prunelloides*, *Ruellia patula*, *Senecio erubescens*, *S. inornatus*, *Spermacoce natalensis*, *Vernonia oligocephala*, *Vigna unguiculata*. Geophytic Herbs: *Hypoxis rigidula*, *Pelargonium luridum*.

Conservation Endangered. Target 19%. None of the area is protected in statutory conservation areas. Highly transformed (58%), mostly by cultivation. This is high-potential agricultural land, which is already been much transformed to sugar cane. Most of the area is communal land. Large areas close to towns (e.g. Mtubatuba) are becoming an urban sprawl. Very little of the natural plant communities remains intact. Heavy grazing has depleted the grasslands and wood harvesting has depleted the bush clumps, reducing them to only the resistant and less useful species. Stunted forms of many of the woody species (e.g. *Euclea*, *Diospyros*, *Gymnosporia*, *Maytenus*) invade the grasslands in many places. Currently it is rare to find a site still with its natural plant composition. *Themeda triandra*, a 'decreaser species', has declined to critically low levels. Alien plant invasions are a threat, with *Chromolaena odorata* being the most problematic. Erosion low to moderate.

Remarks Owen Sithole (Cwaka) Agricultural College is a large estate containing SVl 24 Zululand Coastal Thornveld. A distinction from neighbouring SVl 23 Zululand Lowveld is that the latter is often tree-dominated woodland with tall grassveld.

References Camp (1999a), Van der Linden et al. (2005).

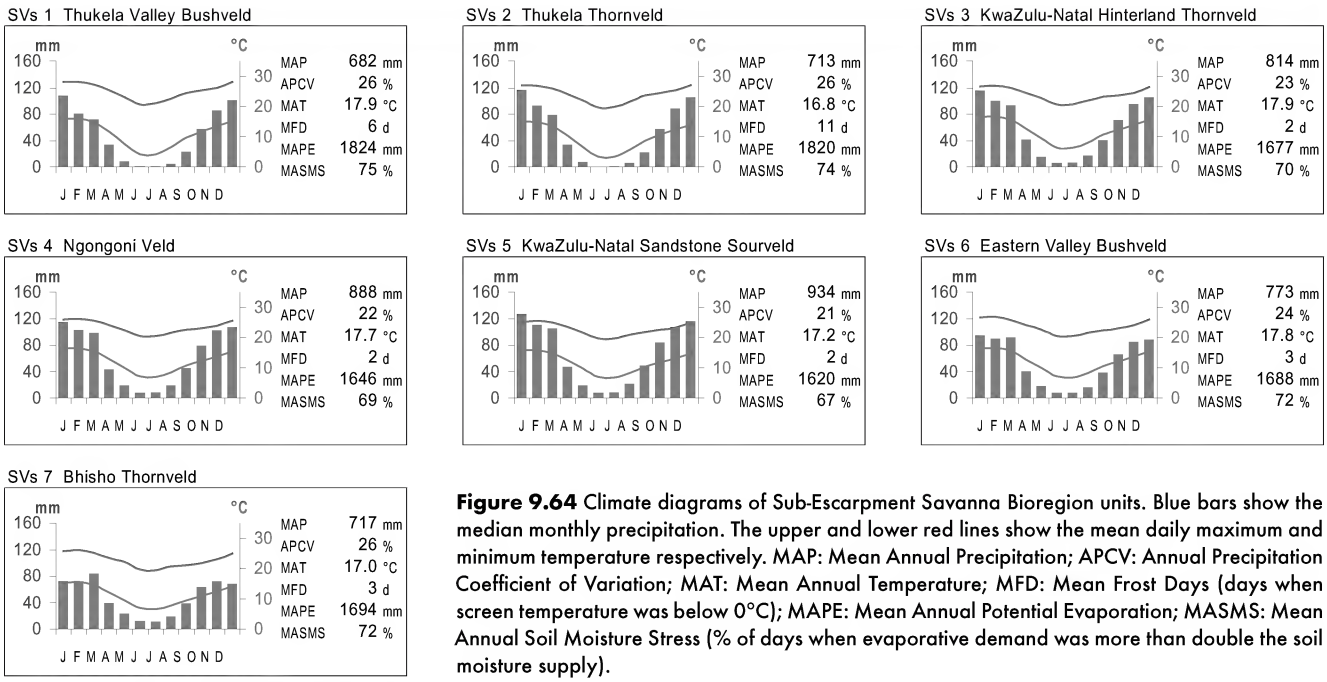


Figure 9.64 Climate diagrams of Sub-Escarpment Savanna Bioregion units. Blue bars show the median monthly precipitation. The upper and lower red lines show the mean daily maximum and minimum temperature respectively. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days (days when screen temperature was below 0°C); MAPE: Mean Annual Potential Evaporation; MASMS: Mean Annual Soil Moisture Stress (% of days when evaporative demand was more than double the soil moisture supply).

Sub-Escarpment Savanna

SVs 1 Thukela Valley Bushveld

VT 23 Valley Bushveld (85%) (Acocks 1953). E 6.3C Semi-deciduous Bush (*Acacia–Boscia–Olea–Schotia* Scrub) (38%), E 6.4C Interior *Acacia karroo–A. nilotica* Thorn Veld (33%) (Edwards 1967). LR 5 Valley Thicket (59%) (Low & Rebelo 1996). BRG 21 Valley Bushveld (99%) (Camp 1999e).

Distribution KwaZulu-Natal Province: Central Thukela River basin upstream of Jameson's Drift, past Tugela Ferry to about 20 km southeast of Ladysmith. Also in valleys of several major tributaries, such as the lower Mooi, Bushmans, Buffels and Sundays Rivers. Altitude about 350–1 000 m.

Vegetation & Landscape Features Often rocky rugged slopes and terraces mainly with deciduous trees of short to medium height (and many large shrubs) including *Acacia tortilis*, *A. nilotica* and *A. natalitia* and prominent evergreen species such as *Olea europaea* subsp. *africana*, *Boscia albitrunca* and *Euclea crispa* in places. Succulent plants, mainly species of *Euphorbia* and *Aloe* occur on shallow and eroded soils. Relatively limited areas are dominated by succulents such as *E. tirucalli* (some hillsides south of the Thukela) and *E. ingens* on steep slopes, but also commonly on the valley floor.

Geology & Soils Shallow soils of Mispah and Glenrosa forms on the slopes, while in valley bottoms, pockets of deep alluvial soils as well as calcareous, duplex soils are found. The major geological formations are sediments of Ecca Group (Karoo Supergroup) and in the eastern part also Archaean granites. Land types mainly Fc and Fb, with some Ae and Ea.

Climate Summer rainfall with dry winters. MAP about 500–850 mm. Frost fairly infrequent and usually on valley bottoms. Mean monthly maximum and minimum temperatures for Muden 36.7°C and 0.2°C and for Weenen 38.1°C and –4.4°C both for December and June, respectively. See also climate diagram for SVs 1 Thukela Valley Bushveld.

B. Forbes

Figure 9.65 SVs 1 Thukela Valley Bushveld: Degraded Thukela Valley Bushveld near Muden showing encroachment by *Euphorbia pseudocactus* and *Blepharis natalensis*.

Important Taxa Tall Tree: *Sclerocarya birrea* subsp. *caffra*. Small Trees: *Combretum apiculatum* (d), *Spirostachys africana* (d), *Acacia tortilis* subsp. *heteracantha*, *Berchemia zeyheri*, *Boscia albitrunca*, *Combretum molle*, *Cussonia spicata*, *Pappea capensis*, *Schotia brachypetala*. Succulent Trees: *Aloe marlothii* subsp. *marlothii* (d), *Euphorbia grandidens* (d), *E. tirucalli* (d), *E. ingens*, *E. triangularis*. Tall Shrubs: *Coddia rudis* (d), *Dichrostachys cinerea* (d), *Euclea crispa* subsp. *crispa*, *E. schimperi*, *Gymnosporia buxifolia*, *Heteromorpha arborescens* var. *abyssinica*, *Olea europaea* subsp. *africana*, *Rhus pentheri*, *Vitex rehmannii*. Low Shrubs: *Barleria obtusa*, *Gymnosporia glaucophylla*. Soft Shrubs: *Hypoestes aristata* (d), *Peristrophe cernua*. Succulent Shrub:

Huernia hystrix subsp. *hystrix*. Woody Climbers: *Asparagus falcatus*, *Jasminum multipartitum*. Woody Succulent Climber: *Sarcostemma viminale*. Graminoids: *Heteropogon contortus* (d), *Melinis repens* (d), *Panicum maximum* (d), *Themeda triandra* (d), *Aristida congesta*, *A. diffusa*, *Cymbopogon pospischilii*, *Eragrostis chloromelas*, *E. curvula*, *Panicum deustum*, *Urochloa mosambicensis*. Succulent Herbs: *Aloe mudenensis*, *Bulbine narcissifolia*, *Duvalia polita, Orbea woodii.*

Biogeographically Important Taxa (Thukela Basin endemics) Small Tree: *Vitellariopsis dispar*. Succulent Herbs: *Aloe prinslooi*, *Orbea woodii*.

Endemic Taxa Small Tree: *Encephalartos cerinus*. Tall Shrub: *Gymnosporia macrocarpa*. Low Shrubs: *Blepharis natalensis* (d), *Barleria argillicola*. Succulent Shrub: *Euphorbia pseudocactus* (d). Succulent Herb: *Gasteria tukhelensis*. Succulent Herbaceous Climber: *Ceropegia cycniflora*.

Conservation Least threatened. Target 25%. Statutorily conserved (less than 200 ha) in the Weenen Game Reserve. This vegetation unit has undergone considerable degradation over almost its entire area. In the many eroded areas, prolonged continuous overgrazing has led to the complete destruction of the grass cover. Often the only ground cover is found under *Acacia tortilis* trees where their root systems retain soil, the trees act as nutrient pumps and provide shade (Camp 1999e). Erosion very variable, ranging from very low to very high. Alien plants include the widely scattered *Opuntia imbricata*.

Remarks Very steep and exposed (well-insolated and dry) rocky habitats support succulent flora including, for example, *Aloe rupestris* and *A. mudenensis*. In the last four decades there has been a substantial increase in woody plant cover, mainly *Acacia tortilis*, at altitudes roughly below 1 000 m in the Weenen/Muden area and possibly related to reduced incidence of fire (Hoffman & O'Connor 1999).

References West (1951), Edwards (1967), Camp (1999e).

SVs 2 Thukela Thornveld

VT 23 Valley Bushveld (58%) (Acocks 1953). E 6.4C Interior *Acacia karroo–A. nilotica* Thorn Veld (61%) (Edwards 1967). LR 25 Natal Central Bushveld (55%) (Low & Rebelo 1996). BRG 18 Mixed Thornveld (98%) (Camp 1999d).

Distribution KwaZulu-Natal Province: Upper Thukela River basin fringing the SVs 1 Thukela Valley Bushveld on its upper border in a series of discontinuous patches. Largest area east of Estcourt–Colenso and including Ladysmith. Also some outliers on slopes south of Dundee. Altitude 900–1 300 m.

Vegetation & Landscape Features The dominant landscape features are valley slopes to undulating hills. Vegetation is *Acacia*-dominated bushveld of variable density (ranging from wooded grassland to dense thickets) with dense grassy undergrowth.

Geology & Soils Broad variety of soils ranging from vertisols and solodised solonetzic soils to transitional fersiallitic soils (Edwards 1967) developing over Karoo Supergroup sediments of the Beaufort and Ecca Groups). Heavy soils are developed over Jurassic dolerite intrusions forming koppies and sills. Land types Fb, Fa, Db, Ea, Fc and Dc.

Climate Summer rainfall with dry summers. MAP about 550–850 mm. Frost fairly infrequent, occurring mainly on the flats. Mean monthly maximum and minimum temperatures for Ladysmith 36.1°C and –3.6°C for January and July, respectively. Corresponding values for Escourt-TNK 34.5°C and –2.3°C for January and June, respectively. See also climate diagram for SVs 2 Thukela Thornveld.

Important Taxa Small Trees: *Acacia natalitia* (d), *A. nilotica* (d), *A. sieberiana* var. *woodii*, *A. tortilis* subsp. *heteracantha*, *Allophylus melanocarpus*, *Boscia albitrunca*, *Clausena anisata*, *Cussonia spicata*, *Dais cotinifolia*, *Ziziphus mucronata*. Tall Shrubs: *Coddia rudis* (d), *Buddleja saligna*, *Clerodendrum glabrum*, *Euclea crispa* subsp. *crispa*, *Heteromorpha arborescens* var. *abyssinica*, *Hibiscus calyphyllus*, *Lippia javanica*, *Pachystigma macrocalyx*, *Rhus pentheri*, *R. rehmanniana*. Low Shrubs: *Barleria obtusa*, *Justicia flava*. Soft Shrub: *Peristrophe cernua*. Woody Succulent Climber: *Senecio brachypodus*. Graminoids: *Eragrostis curvula* (d), *Hyparrhenia hirta* (d), *Melinis repens* (d), *Panicum maximum* (d), *Themeda triandra* (d), *Tristachya leucothrix* (d), *Aristida congesta*, *Digitaria eriantha* subsp. *eriantha*, *Elionurus muticus*, *Eragrostis chloromelas*, *E. superba*, *Heteropogon contortus*, *Setaria sphacelata*, *Sporobolus pyramidalis*. Herb: *Osteospermum muricatum*. Geophytic Herb: *Sansevieria hyacinthoides*. Succulent Herb: *Aloe mudenensis*.

Biogeographically Important Taxa (Thukela Basin endemics) Small Tree: *Vitellariopsis dispar*. Succulent Herbs: *Aloe prinslooi*, *Orbea woodii*.

R. de la Harpe

Figure 9.66 SVs 2 Thukela Thornveld: Open thornveld in the Weenen Game Reserve northeast of Estcourt. *Acacia natalitia* is the prominant tree in the foreground and *A. sieberiana* in the middle distance.

Endemic Taxon Small Tree: *Encephalartos msinganus*.

Conservation Least threatened. Target 25%. Statutorily conserved (less than 1 500 ha) in Weenen Game Reserve and Isandlwana Nature Reserve. About 5% already transformed, mainly by cultivation. Erosion somewhat less than in SVs1 Thukela Valley Bushveld.

Remarks Edwards (1967), echoed by Camp (1999d), claims that an estimated 60% of the thornveld invaded the region this century by an outward migration (encroachment) of *Acacia* species from Thukela River Valley vegetation into presumed original *Themeda–Hyparrhenia* grasslands, but neither of the cited sources provided conclusive evidence to support this suggestion. However, in the last four decades there has been a substantial increase in woody plant cover,

mainly *A. karroo*, at altitudes roughly above 1 000 m in the Weenen/Muden area and possibly related to reduced incidence of fire (Hoffman & O'Connor 1999).

References West (1951), Edwards (1967), Camp (1999d), Breebaart et al. (2001).

SVs 3 KwaZulu-Natal Hinterland Thornveld

VT 5 Ngongoni Veld (41%), VT 23 Valley Bushveld (32%) (Acocks 1953). LR 5 Valley Thicket (46%), LR 24 Coast-Hinterland Bushveld (36%) (Low & Rebelo 1996). BRG 17 Coast Hinterland Thornveld (97%) (Camp 1999d).

Distribution KwaZulu-Natal Province: Patches, scattered immediately above SVs 6 Eastern Valley Bushveld, at altitudes 450–900 m in river valleys of mainly the Mpisi (in the Thukela River catchment), Mvoti, Umgeni (below the Howick Falls), Mlazi, and Lufafa (vicinity of Ixopo) and Mtungwane (tributaries of the Mkomazi).

Vegetation & Landscape Features Vegetation is open thornveld dominated by *Acacia* species on undulating plains found on upper margins of river valleys.

Geology & Soils Shallow sandy soils (Glenrosa and Mispah forms) developing over Ordovician Natal Group sandstones and compact, clayey soils on Dwyka diamictites (Karoo Supergroup) as well as on layered quartz-feldspar metasediments (Mapumulo Group, Mokolian) and granites of the Oribi Gorge Suite (also Mokolian). Land types mainly Fa and Fb with some Ca, Bd and Ac.

Climate Summer rainfall pattern, with some rain in winter. MAP about 650–1 000 mm. Frost infrequent. Mean monthly maximum and minimum temperatures for Pietermaritzburg 37.2°C and –1.8°C for January and June, respectively. See also climate diagram for SVs 3 KwaZulu-Natal Hinterland Thornveld.

Important Taxa Tall Tree: *Acacia robusta*. Small Trees: *Acacia natalitia* (d), *A. nilotica* (d), *Combretum molle* (d), *Ziziphus mucronata* (d), *Brachylaena elliptica*, *Cussonia spicata*, *Erythrina latissima*. Succulent Trees: *Aloe marlothii* subsp. *marlothii*, *Euphorbia ingens*. Tall Shrubs: *Calpurnia aurea*, *Coddia rudis*, *Diospyros dichrophylla*, *Ehretia rigida* subsp. *rigida*, *Grewia occidentalis*, *Gymnosporia buxifolia*, *Hibiscus calyphyllus*, *Rhus pentheri*. Low Shrubs: *Barleria obtusa*, *Chaetacanthus setiger*, *Crossandra greenstockii*, *Justicia flava*. Soft Shrub: *Hypoestes aristata* (d). Woody Climbers: *Jasminum breviflorum*, *Putterlickia verrucosa*, *Tecoma capensis*. Woody Succulent Climber: *Sarcostemma viminale*. Graminoids: *Aristida junciformis* subsp. *junciformis* (d), *Eragrostis curvula* (d), *Hyparrhenia hirta* (d), *Melinis nerviglumis* (d), *Themeda triandra* (d), *Cymbopogon nardus*, *Eragrostis capensis*, *E. chloromelas*, *E. racemosa*, *E. superba*, *Heteropogon contortus*, *Panicum maximum*, *Sporobolus fimbriatus*, *S. pyramidalis*, *Tristachya leucothrix*. Herbs: *Commelina africana*, *Ruellia patula*. Geophytic Herb: *Sansevieria hyacinthoides*.

Biogeographically Important Taxon (Southern distribution limit) Low Shrub: *Barleria elegans*.

Endemic Taxon Succulent Herb: *Aloe pruinosa*.

Conservation Vulnerable. Target 25%. None conserved in statutory conservation areas. Some 22% already transformed by cultivation and some urban or built-up areas. Erosion is low to very low, with some areas of moderate erosion.

Remark 1 Camp (1999e) suggested that his 'Coast Hinterland Thornveld' (identical with this vegetation unit) was originally *Acacia sieberiana* wooded grassland, and woodland before major disturbance occurred, but evidence is largely lacking.

Remark 2 This vegetation unit can be distinguished from SVs 2 Thukela Thornveld by higher floristic richness and a different vegetation structure (scrub and clump character). These differences are linked by Camp (1999d) to milder climatic conditions with less frequent, lighter and localised frosts in this unit.

Remark 3 One of the most prominent woody components of this unit identified in earlier literature sources as *Acacia karroo* Hayne appears to be *A. natalitia* E.Mey. (Coates Palgrave 2002, p. 291).

Reference Camp (1999d).

SVs 4 Ngongoni Veld

VT 5 Ngongoni Veld (59%) (Acocks 1953). LR 24 Coast-Hinterland Bushveld (38%), LR 42 Moist Upland Grassland (24%) (Low & Rebelo 1996). BRG 3 Moist Coast Hinterland Ngongoni Veld (44%), BRG 4 Dry Coast Hinterland Ngongoni Veld (26%) (Camp 1999a).

Distribution KwaZulu-Natal and Eastern Cape Provinces: From Melmoth in the north to near Libode in the former Transkei (including Eshowe, New Hanover, Camperdown, Eston, Richmond, Dumisa, Harding, Lusikisiki and the Libode area). Altitude 400–900 m.

Vegetation & Landscape Features Dense, tall grassland overwhelmingly dominated by unpalatable, wiry Ngongoni grass (*Aristida junciformis*), with this monodominance associated with low species diversity. Wooded areas (thornveld) are found in valleys at lower altitudes, where this vegetation unit

L. Mucina

Figure 9.67 SVs 4 Ngongoni Veld: Species-rich grasslands dominated by *Aristida junciformis* grazed by large indigenous grazers such as impala (*Aepyceros melampus*) and Burchell's zebra (*Equus burchellii*) in the Vernon Crookes Nature Reserve near Scottburgh, southern KwaZulu-Natal.

grades into SVs 3 KwaZulu-Natal Hinterland Thornveld and SVs 7 Bhisho Thornveld. Termitaria support bush clumps with *Acacia* species, *Cussonia spicata*, *Ziziphus mucronata*, *Coddia rudis*, *Ehretia rigida* etc.

Geology & Soils Acid, leached, heavy soils are derived from Karoo Supergroup sediments (including significant Dwyka tillites) and intrusive Karoo dolerites. Also Glenrosa and Mispah soils occur. Land types Fa, Ab, Ac and Aa.

Climate Summer rainfall with some rain in winter. MAP about 700–1 100 mm. Some valleys are sheltered and may show weak rainshadow effects. Frost infrequent, occurring mainly where cold air becomes trapped in valleys. Mean monthly maximum and minimum temperatures for Melmoth 37.0°C and 4.9°C for October and July, respectively. Corresponding values for New Hanover 38.2°C and –0.2°C for January and June, respectively. See also climate diagram for SVs 4 Ngongoni Veld.

Important Taxa Small Trees: *Acacia natalitia*, *A. nilotica*, *A. sieberiana* var. *woodii*. Low Shrubs: *Agathisanthemum bojeri*, *Euryops laxus*, *Gnidia anthylloides*. Graminoids: *Aristida junciformis* subsp. *junciformis* (d), *Bothriochloa insculpta*, *Eragrostis curvula*, *Hyparrhenia hirta*, *Panicum maximum*, *Paspalum scrobiculatum*, *Sporobolus africanus*, *S. pyramidalis*, *Themeda triandra*. Herbs: *Chamaecrista mimosoides*, *Conostomium natalense*, *Gerbera ambigua*, *Helichrysum allioides*, *Hermannia grandistipula*, *Pentanisia prunelloides*, *Selago tarachodes*, *Senecio exuberans*, *Vernonia galpinii*. Geophytic Herbs: *Hypoxis argentea*, *Watsonia densiflora*. Succulent Herb: *Aloe minima*.

Conservation Vulnerable. Target 25%. Only less than 1% of the unit is statutorily conserved in the Ophathe and Vernon Crookes Nature Reserves. Some 39% has been transformed for cultivation, plantations and urban development.

Remarks Within KwaZulu-Natal, this vegetation unit comprises mainly Camp's (1999a) BRG 3 and BRG 4, representing wet and dry forms of Ngongoni veld, respectively. His distinction is based on MAP of 800 mm, which is assumed to have significant agricultural importance (see Camp 2001). Major floristic differences have yet to be shown. Camp (1999a), in accordance with Acocks (1953), considers the Ngongoni Veld to be secondary.

References Killick (1958), Moll (1976), Camp (1999a, 2001).

SVs 5 KwaZulu-Natal Sandstone Sourveld

VT 5 Ngongoni Veld (55%) (Acocks 1953). LR 24 Coast-Hinterland Bushveld (50%) (Low & Rebelo 1996). BRG 3 Moist Coast Hinterland Ngongoni Veld (49%), BRG 5 Moist Midlands Mistbelt (49%) (Camp 1999a, b).

Distribution KwaZulu-Natal Province: Elevated coastal inland sandstone plateaus from Mapumulo near Kranskop in the north to St Faiths near Port Shepstone in the south (including Noodsberg, Hillcrest, Kloof, Table Mountain, Inanda, Stony Hill, Umbumbulu, Mid-Illovo, Dumisa, Highflats). Altitude 500–1 100 m.

Vegetation & Landscape Features Short, species-rich grassland with scattered low shrubs and geoxylic suffrutices. Proteaceae trees and shrubs (*Protea*, *Leucospermum*, *Faurea*) can be locally common. The dominating landscape features are flat (or rolling) plateau tops and steep slopes commonly forming table mountains.

Geology & Soils Ordovician Natal Group sandstones carry shallow, nutrient-poor, skeletal, sandy soils freely drained and including Glenrosa and Mispah forms. Land types Fa, Ac, Aa and Bb.

Climate Summer rainfall with some rain in winter. MAP about 700–1 200 mm. Mist common and important in providing additional moisture. Frost very infrequent. Mean monthly maximum and minimum temperatures for Hillcrest 35.0°C and 4.2°C and for Mid-Illovo 35.8°C and 4.7°C both for October and June/July, respectively. Corresponding values for Dalton 35.6°C and 0.9°C for October and July, respectively. See also climate diagram for SVs 5 KwaZulu-Natal Sandstone Sourveld.

Important Taxa Small Trees: *Protea caffra* (d), *P. roupelliae* subsp. *roupelliae* (d). Tall Shrubs: *Aspalathus chortophila*, *Gnidia kraussiana*, *Pachystigma macrocalyx*. Low Shrubs: *Acalypha glandulifolia*, *Agathisanthemum bojeri*, *Erica cubica* var. *cubica*, *E. natalitia*, *Protea simplex*, *P. welwitschii* subsp. *welwitschii*, *Rhus grandidens*, *Senecio medley-woodii*, *Tetraselago natalensis*, *Thunbergia atriplicifolia*, *Turraea pulchella*. Graminoids: *Aristida junciformis* subsp. *junciformis* (d), *Heteropogon contortus* (d), *Themeda triandra* (d), *Trachypogon spicatus* (d), *Tristachya leucothrix* (d), *Andropogon schirensis*, *Cymbopogon nardus*, *Digitaria diagonalis*, *D. natalensis*, *Diheteropogon amplectens*, *Elionurus muticus*, *Eragrostis plana*, *E. racemosa*, *Eulalia villosa*, *Hyparrhenia hirta*, *Monocymbium ceresiiforme*. Herbs: *Aster bakerianus*, *Cyanotis speciosa*, *Dianthus zeyheri*, *Helichrysum allioides*, *Selago tarachodes*, *Senecio dregeanus*, *Zaluzianskya pilosa*. Geophytic Herbs: *Aspidoglossum ovalifolium*, *Brachystelma perditum*, *B. pygmaeum* subsp. *flavidum*, *B. tenellum*, *Eriospermum mackenii*, *Watsonia densiflora*. Succulent Herbs: *Aloe minima*, *Senecio oxyriifolius*.

Biogeographically Important Taxa ([M]Midlands endemic, [P]Link to Pondoland, [F]Fynbos generic element, [S]Southern distribution limit) Low Shrubs: *Agathosma ovata*[F], *Erica aspalathifolia*[P], *Eriosemopsis subanisophylla*[P], *Gnidia woodii*[P],

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Figure 9.68 SVs 5 KwaZulu-Natal Sandstone Sourveld: Short grassland with the range-restricted *Gladiolus inandensis* in the Vernon Crookes Nature Reserve.

Leucospermum gerrardii[F], *Muraltia lancifolia*[P,F], *Stangeria eriopus*[P], *Syncolostemon parviflorus*[P]. Herbs: *Agathisanthemum chlorophyllum*[P], *Callilepis leptophylla*[S], *Helichrysum acutatum*[P], *H. griseum*[P], *H. pannosum*[P]. Geophytic Herbs: *Dierama pallidum*[M], *D. pumilum*[M], *Disperis woodii*[P], *Gladiolus inandensis*[P]. Succulent Herbs: *Bulbine inflata*[S], *Crassula multicava* subsp. *floribunda*[P]. Geoxylic Suffrutex: *Rhus rudatisii*[P].

Endemic Taxa Low Shrubs: *Helichrysum woodii*, *Tephrosia inandensis*. Succulent Herbaceous Climber: *Crassula inandensis*. Herbs: *Eriosema populifolium* subsp. *populifolium*, *E. rossii*, *Phymaspermum pinnatifidum*. Geophytic Herbs: *Brachystelma modestum*, *B. natalense*, *B. pulchellum*, *Cynorkis compacta*, *Gladiolus cruentus*, *Hesperantha gracilis*.

Conservation Endangered. Target 25%. Only 0.2% statutorily conserved in the Krantzkloof and Vernon Crookes Nature Reserves. Some 68% transformed for cultivation, plantations, urban development or road building. This highly transformed vegetation type is a prime agricultural area with mainly sugar cane and timber plantations. The urban sprawl of the Ethekwini (Durban) Metropolitan Area and densely populated subsistence farming areas account for most of the remainder. Apart from the critically little conserved areas (only several hundred hectares), most remaining areas are subjected to high levels of grazing and frequent fire not conducive to the recruitment of seedlings of many of the shrubs and herbs. Erosion is low to very low.

Remark 1 This vegetation unit shares a number of endemic species with CB 4 Pondoland-Ugu Sandstone Coastal Sourveld.

Remark 2 Biome affiliation of this unit is borderline and it could also be considered a candidate for the Grassland Biome.

References Killick (1958), Camp (1999a, b), Scott-Shaw (1999).

SVs 6 Eastern Valley Bushveld

VT 23 Valley Bushveld (56%) (Acocks 1953). LR 5 Valley Thicket (58%) (Low & Rebelo 1996).

Distribution KwaZulu-Natal and Eastern Cape Provinces: Deeply incised valleys of rivers including the lower reaches of the Thukela, Mvoti, Mgeni, Mlazi, Mkhomazi, Mzimkulu, Mzimkulwana, Mtamvuna, Mtentu, Msikaba, Mzimvubu (and its several tributaries), Mthatha, Mbhashe, Shixini, Qhorha and Great Kei. Very seldom extending to the coast. Altitude 100–1 000 m.

Vegetation & Landscape Features Semideciduous savanna woodlands in a mosaic with thickets, often succulent and dominated by species of *Euphorbia* and *Aloe*. Most of the river valleys run along a northwest-southeast axis which results in unequal distribution of rainfall on respective north-facing and south-facing slopes since the rain-bearing winds blow from the south. The steep north-facing slopes are sheltered from the rain and also receive greater amounts of insolation adding to xerophilous conditions on these slopes.

Geology & Soils The area is underlain by the sediments of the Karoo Supergroup with the mudstones and lesser sandstones of the Adelaide and Tarkastad Subgroups (Beaufort Group) dominant, and some Ecca Group shale. Dominant land type Fa.

Climate Summer rainfall with some rain in winter. MAP about 550–1 000 mm. Frost infrequent. Mean monthly maximum and minimum temperatures for Nagle Dam 36.9°C and 4.0°C for December and June, respectively. See also climate diagram for SVs 6 Eastern Valley Bushveld.

Important Taxa Tall Trees: *Acacia robusta*, *Sclerocarya birrea* subsp. *caffra*. Small Trees: *Acacia natalitia* (d), *A. nilotica* (d), *Combretum molle* (d), *Spirostachys africana* (d), *Acacia tortilis* subsp. *heteracantha*, *Berchemia zeyheri*, *Boscia albitrunca*, *Brachylaena elliptica*, *Cussonia spicata*, *Dombeya rotundifolia*, *Encephalartos natalensis*, *E. villosus*, *Hippobromus pauciflorus*, *Schotia brachypetala*, *Ziziphus mucronata*. Succulent Trees: *Euphorbia tirucalli* (d), *Aloe marlothii* subsp. *marlothii*, *A. rupestris*, *Euphorbia ingens*, *E. triangularis*. Tall Shrubs: *Dichrostachys cinerea* (d), *Calpurnia aurea*, *Coddia rudis*, *Ehretia rigida* subsp. *rigida*, *Euclea crispa* subsp. *crispa*, *Grewia occidentalis*, *Olea europaea* subsp. *africana*. Succulent Shrubs: *Aloe arborescens*, *Euphorbia grandicornis*, *Kleinia fulgens*. Soft Shrubs: *Hypoestes aristata*, *Peristrophe cernua*. Woody Climber: *Acacia brevispica* subsp. *dregeana*. Herbaceous Climber: *Ischnolepis natalensis*. Graminoids: *Aristida congesta* (d), *Eragrostis curvula* (d), *Hyparrhenia hirta* (d), *Melinis repens* (d), *Panicum maximum* (d), *Themeda triandra* (d), *Cymbopogon pospischilii*, *Eragrostis superba*, *Heteropogon contortus*, *Panicum deustum*, *Sporobolus fimbriatus*, *S. pyramidalis*, *Tristachya leucothrix*, *Urochloa mosambicensis*. Herbs: *Achyranthes aspera*, *Hibiscus pedunculatus*. Geophytic Herb: *Sansevieria hyacinthoides*.

Endemic Taxa Tall Shrub: *Bauhinia natalensis*. Succulent Herb: *Huernia pendula*.

Conservation Least threatened. Target 25%. Only 0.8% statutorily conserved, mainly in the Luchaba Wildlife Reserve; small patches also conserved in the Oribi Gorge Nature Reserve. Some 15% transformed mainly by cultivation. Alien plant invasions are a serious threat, with *Chromolaena odorata*, *Lantana camara* and *Caesalpinia decapetala* being most problematic.

Remarks This unit (together with the SVs 1 Thukela Valley Bushveld) corresponds closely to Acocks's (1953) 'Northern Variation of the Valley Bushveld' from the Great Kei River Valley northwards. He viewed this area as transitional to

H.F. Glen

Figure 9.69 SVs 6 Eastern Valley Bushveld: Moderately dense bushveld between Mpisi River and Emabhobhane Drift on the lower Thukela River with *Ehretia rigida*, *Boscia albitrunca*, *Croton pseudopulchellus* (grey shrubs), *Euphorbia grandicornis* and *Aloe marlothii*.

the Lowveld, particularly that part from the Umkomaas River Valley northwards. Its northern variation (i.e. from the Kei northwards) is more open than his southern variation (the latter is a part of the Albany Thicket Biome) and includes 'more grass, fewer succulents and more species of definitely tropical nature'. Examples of species of this unit that extend southwards from at least the lowveld savanna of Mpumalanga, or from savanna elsewhere at this northern latitude are *Acacia nilotica*, *Euphorbia ingens*, *Spirostachys africana* and *Vitex rehmannii* (extending southwards as far as the Umkomaas River Valley), *Combretum molle* and *Dichrostachys cinerea* (extending further south to around the southern border of KwaZulu-Natal), and *A. robusta*, *Dalbergia obovata*, *Dombeya cymosa*, *E. tirucalli* and *Vangueria infausta* (extending to the vicinity of the Great Kei River Valley or enter the easternmost extremity of the Albany Thicket Biome). In contrast to the thicket vegetation found in valleys south of the Great Kei River, Vlok & Euston-Brown (2002) found that most of the Kei Valley does not have extensive stands of thicket and that thicket only occurs as small clumps, usually on north-facing slopes in a matrix of savanna. Despite considerable disturbance to the vegetation here, they stated that there was no direct evidence that thicket did occur in more extensive stands in recent times. Only over a short length along the lower Great Kei River does true Albany Thicket Biome occur (mapped as part of AT 12 Buffels Thicket; see chapter on Albany Thicket in this book).

L. Mucina

Figure 9.70 SVs 7 Bhisho Thornveld: Thornveld dominated by *Acacia natalitia* near Butterworth, Transkei, Eastern Cape.

References Edwards (1967), Morris (1967, 1969), Grunow & Morris (1969), Perkins (1997), Perkins et al. (1999).

SVs 7 Bhisho Thornveld

VT 7 Eastern Province Thornveld (37%), VT 23 Valley Bushveld (23%) (Acocks 1953). LR 16 Eastern Thorn Bushveld (50%) (Low & Rebelo 1996).

Distribution Eastern Cape Province: From near Mthatha in a band parallel to but inland of the coast to north of East London, turning to run along the southern side of the Amathole Mountains as far as Fort Beaufort. Also on dissected hills and low mountains around Grahamstown, especially to the southwest, and in a few fragments in valleys northeast of the Amathole Mountains. Altitude mostly 200–700 m.

Vegetation & Landscape Features On undulating to moderately steep slopes, sometimes in shallow, incised drainage valleys. Open savanna characterised by small trees of *Acacia natalitia* with a short to medium, dense, sour grassy understorey, usually dominated by *Themeda triandra* when in good condition. A diversity of other woody species also occur, often increasing under conditions of overgrazing.

Geology & Soils Mudstone with subordinate sandstone of the Adelaide Subgroup (Beaufort Group, Karoo Supergroup) underlies most of the area and is intruded by Karoo dolerite dykes and sills. The substrate is primarily loamy soils, but there is significant variability. The area was classified into a variety of land types, with Fa and Fb dominant.

Climate Summer rainfall with some rain in winter. MAP from about 500 mm in the west to more than 900 mm in the east. The coefficient of variation in MAP is approximately 25%, but varies from about 20% at the coast to about 30% on the inland and western parts. Frost infrequent. The mean daily maximum temperatures for January 25°C in the east and 28°C in the west and the mean daily minimum temperatures for July 3°C inland and 9°C at the coast. Mean monthly maximum and minimum temperatures for King William's Town 37.0°C and –1.6°C for February and June, respectively. See also climate diagram for SVs 7 Bhisho Thornveld.

Important Taxa Small Tree: *Acacia natalitia* (d). Tall Shrub: *Tephrosia capensis*. Low Shrubs: *Anthospermum rigidum* subsp. *pumilum*, *Chrysocoma ciliata*, *Felicia muricata*. Graminoids: *Eragrostis plana* (d), *Heteropogon contortus* (d), *Hyparrhenia hirta* (d), *Sporobolus africanus* (d), *Themeda triandra* (d), *Aristida junciformis* subsp. *junciformis*, *Bulbostylis humilis*, *Cynodon dactylon*, *Digitaria diagonalis*, *D. eriantha* subsp. *eriantha*, *Elionurus muticus*, *Eragrostis capensis*, *E. chloromelas*, *E. curvula*, *Kyllinga alata*, *Microchloa caffra*, *Paspalum dilatatum*, *Schoenoxiphium sparteum*. Herbs: *Centella asiatica*, *Commelina africana*, *Gazania linearis*, *Gerbera ambigua*, *Helichrysum miconiifolium*, *H. nudifolium* var. *pilosellum*, *H. rugulosum*, *Senecio retrorsus*, *Spermacoce natalensis*, *Wahlenbergia stellarioides*, *Zornia capensis*. Geophytic Herbs: *Hypoxis argentea*, *Moraea polystachya*, *Pellaea calomelanos*.

Conservation Least threatened. Target 25%. Only 0.2% statutorily conserved in the Doubledrift and Thomas Baines Nature Reserves. About 2% conserved in private reserves such as Shamwari Game Reserve, Rockdale Game Ranch and Fourie Safaris Game Farm. Some 20% already transformed for cultivation, urban development or plantations. Erosion is very low to moderate.

Remarks Due to the wide distribution of this unit, it incorporates a wide variety of environmental conditions. It borders on a number of other units and species from different vegetation types may co-occur along overlapping areas. Most similar to and forms a gradient to Gs 18 Bedford Dry Grassland in the west. Fire and grazing regimes appear to be key determinants of this vegetation unit, although soil characteristics are also important. *Acacia natalitia*, the main woody species of the SVs 7 Bhisho Thornveld, tends to occur in habitats with high soil moisture balance.

Reference Acocks (1988).

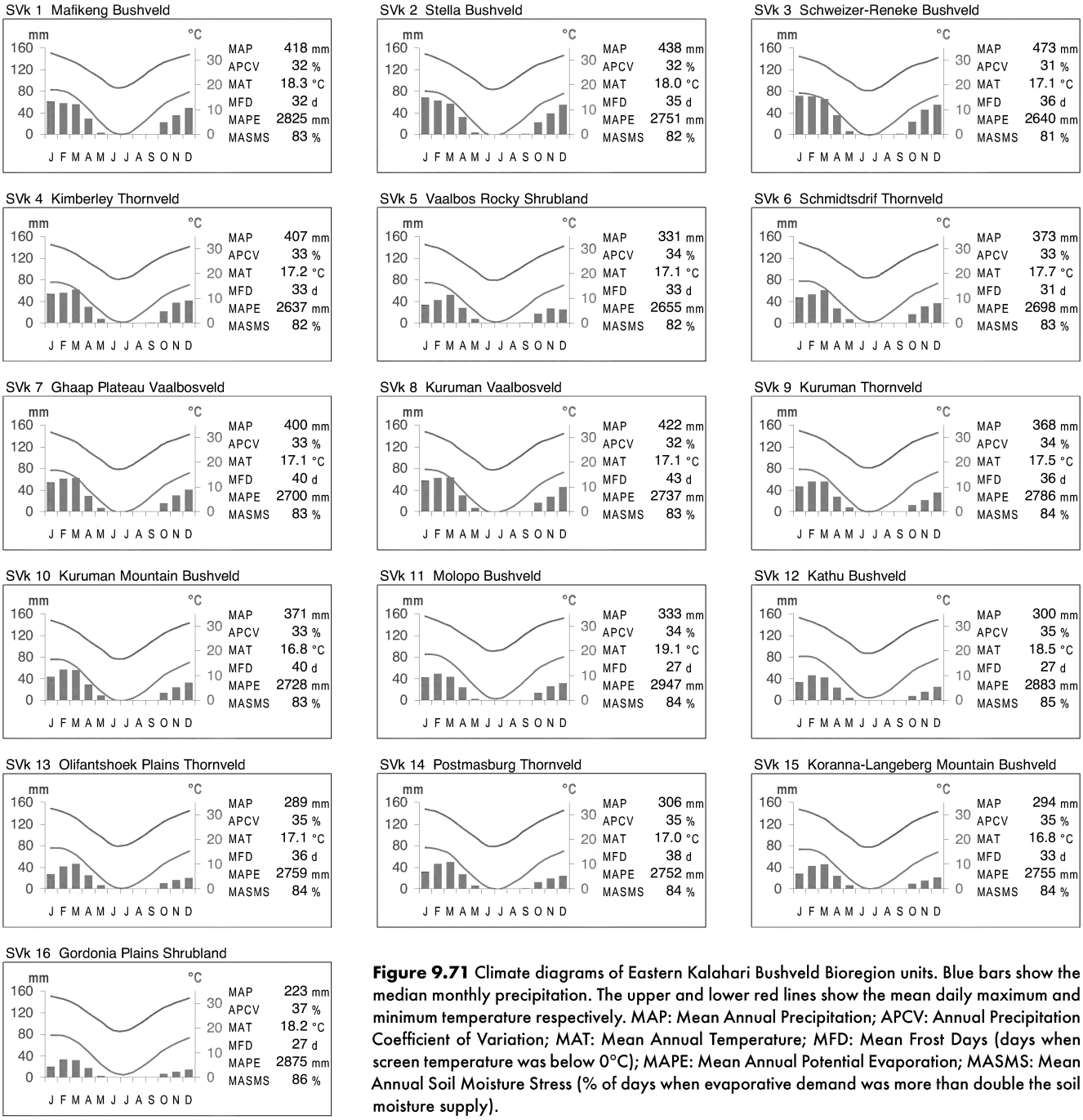

Figure 9.71 Climate diagrams of Eastern Kalahari Bushveld Bioregion units. Blue bars show the median monthly precipitation. The upper and lower red lines show the mean daily maximum and minimum temperature respectively. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days (days when screen temperature was below 0°C); MAPE: Mean Annual Potential Evaporation; MASMS: Mean Annual Soil Moisture Stress (% of days when evaporative demand was more than double the soil moisture supply).

Eastern Kalahari Bushveld

SVk 1 Mafikeng Bushveld

VT 16 Kalahari Thornveld and Shrub Bushveld (76%) (Acocks 1953). LR 30 Kalahari Plains Thorn Bushveld (80%) (Low & Rebelo 1996).

Distribution North-West Province: West of Mafikeng and south of the Botswana border westwards to around Vergeleë, southwards to Piet Plessis and Setlagole. Altitude 1 100–1 400 m.

Vegetation & Landscape Features Well developed tree and shrub layers, dense stands of *Terminalia sericea*, *Acacia luederitzii* and *A. erioloba* in certain areas. Shrubs include *A. karroo*, *A. hebeclada* and *A. mellifera*, *Dichrostachys cinerea*, *Grewia flava*, *G. retinervis*, *Rhus tenuinervis* and *Ziziphus mucronata*. Grass layer is also well developed.

Geology & Soils Aeolian Kalahari sand of Tertiary to Recent age on flat sandy plains, soils deep (>1.2 m). Clovelly and Hutton soil forms. Land types Ah, Ai and Ae.

Climate Summer rainfall with very dry winters. MAP from about 350 mm in the west to about 520 mm in the east. Frost frequent in winter. Mean monthly maximum and minimum temperatures for Mmabatho 35.6°C and –1.8°C for November and June, respectively. See also climate diagram for SVk 1 Mafikeng Bushveld.

Important Taxa Tall Tree: *Acacia erioloba* (d). Small Trees: *Acacia karroo* (d), *A. mellifera* subsp. *detinens* (d), *Terminalia sericea* (d), *Ziziphus mucronata* (d). Tall Shrubs: *Dichrostachys cinerea* (d), *Grewia flava* (d), *Rhus tenuinervis* (d), *Diospyros austro-africana*, *Ehretia rigida* subsp. *rigida*, *Rhigozum obovatum*, *Tarchonanthus camphoratus*. Low Shrubs: *Acacia hebe-*

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Figure 9.72 SVk 1 Mafikeng Bushveld: Open savanna dominated by *Ziziphus mucronata*, *Grewia flava* and *Acacia erioloba* on Wildebeesthoorn between Vergelegeë and Setlagole in the Vryburg District, North-West Province.

clada subsp. *hebeclada* (d), *Grewia retinervis* (d), *Aptosimum procumbens*, *Felicia muricata*, *Gnidia polycephala*, *Helichrysum zeyheri*, *Hoffmannseggia burchellii*, *Lantana rugosa*, *Talinum arnotii*. Geoxylic Suffrutex: *Elephantorrhiza elephantina*. Succulent Shrub: *Lycium cinereum*. Woody Climber: *Asparagus africanus*. Graminoids: *Anthephora pubescens* (d), *Cymbopogon pospischilii* (d), *Digitaria eriantha* subsp. *eriantha* (d), *Eragrostis lehmanniana* (d), *E. pallens* (d), *Schmidtia pappophoroides* (d), *Stipagrostis uniplumis* (d), *Aristida congesta*, *A. meridionalis*, *A. mollissima* subsp. *argentea*, *A. stipitata* subsp. *stipitata*, *Brachiaria nigropedata*, *B. serrata*, *Cynodon dactylon*, *Digitaria argyrograpta*, *Eragrostis superba*, *E. trichophora*, *Melinis repens*, *Tragus racemosus*, *Urochloa panicoides*. Herbs: *Barleria macrostegia*, *Erlangea misera*, *Harpagophytum procumbens* subsp. *procumbens*, *Hermannia tomentosa*, *Hermbstaedtia odorata*, *Indigofera daleoides*, *Limeum fenestratum*, *Nidorella resedifolia*, *Oxygonum dregeanum* subsp. *canescens* var. *canescens*, *Senna italica* subsp. *arachoides*. Geophytic Herb: *Ledebouria marginata*.

Biogeographically Important Taxa (Kalahari endemics) Small Tree: *Acacia luederitzii* var. *luederitzii* (d). Graminoid: *Panicum kalaharense*.

Conservation Vulnerable. Target 16%. None conserved in statutory conservation areas but very small area conserved in the Mmabatho Recreation Area. About 25% already transformed, mainly for cultivation and urban development. Erosion is very low.

Reference Smit (2000).

SVk 2 Stella Bushveld

VT 16 Kalahari Thornveld and Shrub Bushveld (92%) (Acocks 1953). LR 33 Kalahari Plateau Bushveld (73%) (Low & Rebelo 1996).

Distribution North-West Province: North of Vryburg around Stella westwards to Louwna and eastwards to about 20 km west of Delareyville. Altitude 1 250–1 400 m.

Vegetation & Landscape Features Plains to sometimes slightly undulating plains with open tree and shrub layers and trees *Acacia erioloba* and *A. tortilis* and shrubs *A. hebeclada*, *Dichrostachys cinerea*, *Grewia flava* and *Tarchonanthus camphoratus*.

Geology & Soils Andesitic lavas of the Allanridge Formation of the Ventersdorp Supergroup, sometimes covered with silcrete or calcrete of the Kalahari Group, on flat to hilly plains. Sandy soils 0.1–0.9 m deep, various soil forms. Land types Bc and Ae, with a little Ah.

Climate Summer rainfall with very dry winters. MAP about 400–480 mm. Frost frequent in winter. See also climate diagram for SVk 2 Stella Bushveld.

Important Taxa Tall Tree: *Acacia erioloba* (d). Small Trees: *Acacia tortilis* subsp. *heteracantha* (d), *A. caffra*, *A. karroo*, *Rhus lancea*. Tall Shrubs: *Dichrostachys cinerea* (d), *Grewia flava* (d), *Tarchonanthus camphoratus* (d), *Asparagus laricinus*, *Diospyros lycioides* subsp. *lycioides*, *D. pallens*, *Ehretia rigida* subsp. *rigida*. Low Shrubs: *Acacia hebeclada* subsp. *hebeclada* (d), *Chrysocoma ciliata* (d), *Helichrysum zeyheri*, *Pentzia viridis*, *Solanum supinum*. Succulent Shrub: *Hertia pallens*. Woody Climber: *Asparagus africanus*. Herbaceous Climber: *Rhynchosia confusa*. Graminoids: *Cenchrus ciliaris* (d), *Cymbopogon pospischilii* (d), *Eragrostis rigidior* (d), *Panicum coloratum* (d), *Themeda triandra* (d), *Aristida congesta*, *Cynodon dactylon*, *Eragrostis lehmanniana*, *E. obtusa*, *E. superba*, *Pogonarthria squarrosa*, *Sporobolus fimbriatus*, *Tragus racemosus*. Herbs: *Barleria macrostegia*, *Dicoma capensis*, *Hibiscus pusillus*, *Indigofera alternans*, *I. daleoides*, *Lippia scaberrima*, *Osteospermum muricatum*, *Tripteris aghillana*. Geophytic Herb: *Babiana hypogea*.

Conservation Vulnerable. Target 16%. None conserved in statutory conservation areas. Some 21% transformed, almost all by cultivation. Erosion is very low.

Reference Smit (2000).

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Figure 9.73 SVk 2 Stella Bushveld: Open savanna on plains with *Acacia erioloba*, *Tarchonanthus camphoratus*, *A. hebeclada* and *Eragrostis lehmanniana* var. *lehmanniana* on Klipfontein between Vryburg and Ganyesa, North-West Province.

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Figure 9.74 SVk 3 Schweizer-Reneke Bushveld: Open shrubland dominated by *Acacia hebeclada* and *Tarchonanthus camphoratus* with some *A. karroo* trees on Nieuwjaarsfontein west of Schweizer-Reneke, North-West Province.

SVk 3 Schweizer-Reneke Bushveld

VT 16 Kalahari Thornveld and Shrub Bushveld (89%) (Acocks 1953). LR 32 Kimberley Thorn Bushveld (88%) (Low & Rebelo 1996).

Distribution North-West Province: Schweizer-Reneke area in the east to Amalia in the west and from the farming areas of around Broedersput in the north to Never Mind (Christiana District) in the south. Altitude 1 250–1 400 m.

Vegetation & Landscape Features Plains, slightly undulating plains and some hills, supporting open woodland with a fairly dense shrub layer, with trees *Acacia erioloba*, *A. karroo*, *A. tortilis*, *Rhus lancea* and shrubs *A. hebeclada*, *Diospyros lycioides*, *Grewia flava*, *Tarchonanthus camphoratus*.

Geology & Soils Andesitic lavas of the Allanridge Formation of the Ventersdorp Supergroup, sometimes covered with silcrete or calcrete of the Kalahari Group. Deep (0.9–1.2 m) sandy soils, with Hutton and Clovelly the dominant soil forms. Land types Ah and Ae and some Bc.

Climate Rainfall in summer with very dry winters. MAP about 440–520 mm. Frost frequent in winter. See also climate diagram for SVk 3 Schweizer-Reneke Bushveld.

Important Taxa Tall Tree: *Acacia erioloba* (d). Small Trees: *Acacia karroo* (d), *A. tortilis* subsp. *heteracantha* (d), *Rhus lancea* (d). Tall Shrubs: *Asparagus laricinus* (d), *Diospyros lycioides* subsp. *lycioides* (d), *Grewia flava* (d), *Tarchonanthus camphoratus* (d), *Diospyros pallens*, *Ehretia rigida* subsp. *rigida*, *Gymnosporia buxifolia*, *Rhus tridactyla*. Low Shrubs: *Acacia hebeclada* subsp. *hebeclada* (d), *Aptosimum decumbens*, *Chrysocoma ciliata*, *Gnidia polycephala*, *Pentzia viridis*. Woody Climber: *Asparagus africanus*. Graminoids: *Anthephora pubescens* (d), *Digitaria eriantha* subsp. *eriantha* (d), *Heteropogon contortus* (d), *Stipagrostis uniplumis* (d), *Themeda triandra* (d), *Aristida congesta*, *A. stipitata* subsp. *spicata*, *Chloris virgata*, *Cynodon dactylon*, *Eragrostis biflora*, *E. rigidior*, *E. superba*, *E. trichophora*, *Sporobolus fimbriatus*. Herbs: *Barleria macrostegia*, *Hermannia tomentosa*, *Hibiscus pusillus*, *Indigofera daleoides*, *Lippia scaberrima*, *Osteospermum muricatum*, *Pollichia campestris*, *Rhynchosia adenodes*. Geophytic Herbs: *Dipcadi papillatum*, *Nerine laticoma*.

Conservation Endangered. Target 16%. None conserved in statutory conservation areas. Largely (42%) transformed, almost all by cultivation. Erosion is very low.

Reference Smit (2000).

SVk 4 Kimberley Thornveld

VT 16 Kalahari Thornveld and Shrub Bushveld (50%) (Acocks 1953). LR 32 Kimberley Thorn Bushveld (74%) (Low & Rebelo 1996).

Distribution North-West, Free State and Northern Cape Provinces: Most of the Kimberley, Hartswater, Bloemhof and Hoopstad Districts as well as substantial parts of the Warrenton, Christiana, Taung, Boshof and to some extent the Barkly West Districts. Also includes pediment areas in the Herbert and Jacobsdal Districts. Altitude 1 050–1 400 m.

Vegetation & Landscape Features Plains often slightly irregular with well-developed tree layer with *Acacia erioloba*, *A. tortilis*, *A. karroo* and *Boscia albitrunca* and well-developed shrub layer with occasional dense stands of *Tarchonanthus camphoratus* and *A. mellifera*. Grass layer open with much uncovered soil.

Geology & Soils Andesitic lavas of the Allanridge Formation in the north and west and fine-grained sediments of the Karoo Supergroup in the south and east. Deep (0.6–1.2 m) sandy to loamy soils of the Hutton soil form (Ae and Ah land types) on slightly undulating sandy plains.

Climate Summer and autumn rainfall and very dry winters. MAP from about 300 mm in the southwest to about 500 mm in the northeast. Frost frequent in winter. Mean monthly maximum and minimum temperatures for Kimberley 37.5°C and –4.1°C for January and July, respectively. Corresponding values for

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Figure 9.75 SVk 4 Kimberley Thornveld: Open savanna dominated by *Acacia erioloba* and *A. mellifera* on Kloksfontein south-southwest of Kimberley.

Vaalharts-Agr 37.4°C and –3.9°C, respectively. See also climate diagram for SVk 4 Kimberley Thornveld.

Important Taxa Tall Tree: *Acacia erioloba* (d). Small Trees: *Acacia karroo* (d), *A. mellifera* subsp. *detinens* (d), *A. tortilis* subsp. *heteracantha* (d), *Rhus lancea*. Tall Shrubs: *Tarchonanthus camphoratus* (d), *Diospyros pallens*, *Ehretia rigida* subsp. *rigida*, *Euclea crispa* subsp. *ovata*, *Grewia flava*, *Lycium arenicola*, *L. hirsutum*, *Rhus tridactyla*. Low Shrubs: *Acacia hebeclada* subsp. *hebeclada* (d), *Anthospermum rigidum* subsp. *pumilum*, *Helichrysum zeyheri*, *Hermannia comosa*, *Lycium pilifolium*, *Melolobium microphyllum*, *Pavonia burchellii*, *Peliostomum leucorrhizum*, *Plinthus sericeus*, *Wahlenbergia nodosa*. Succulent Shrubs: *Aloe hereroensis* var. *hereroensis*, *Lycium cinereum*. Graminoids: *Eragrostis lehmanniana* (d), *Aristida canescens*, *A. congesta*, *A. mollissima* subsp. *argentea*, *Cymbopogon pospischilii*, *Digitaria argyrograpta*, *D. eriantha* subsp. *eriantha*, *Enneapogon cenchroides*, *E. scoparius*, *Eragrostis rigidior*, *Heteropogon contortus*, *Themeda triandra*. Herbs: *Barleria macrostegia*, *Dicoma schinzii*, *Harpagophytum procumbens* subsp. *procumbens*, *Helichrysum cerastioides*, *Hermbstaedtia odorata*, *Hibiscus marlothianus*, *Jamesbrittenia aurantiaca*, *Lippia scaberrima*, *Osteospermum muricatum*, *Vahlia capensis* subsp. *vulgaris*. Succulent Herbs: *Aloe grandidentata, Piaranthus decipiens*.

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Figure 9.76 SVk 5 Vaalbos Rocky Shrubland: Open shrubland dominated here by *Tarchonanthus camphoratus*, *Acacia tortilis* and *Lycium* species on a rocky hillside on The Grange, north-east of Hopetown, Northern Cape Province.

Biogeographically Important Taxa ([GW]Griqualand West endemic, [K]Kalahari endemic) Low Shrub: *Blepharis marginata*[GW]. Succulent Shrub: *Euphorbia bergii*[GW]. Graminoid: *Panicum kalaharense*[K]. Herbs: *Helichrysum arenicola*[K], *Neuradopsis bechuanensis*[K]. Succulent Herbs: *Lithops aucampiae* subsp. *aucampiae*[GW], *Tridentea marientalensis* subsp. *marientalensis*[K].

Conservation Least threatened. Target 16%. Only 2% statutorily conserved in Vaalbos National Park as well as in Sandveld, Bloemhof Dam and S.A. Lombard Nature Reserves. Some 18% already transformed, mostly by cultivation. Erosion is very low. Area is mostly used for cattle farming or game ranching. Overgrazing leads to encroachment of *Acacia mellifera* subsp. *detinens*.

References Bezuidenhout (1994, 1995), Smit (2000).

SVk 5 Vaalbos Rocky Shrubland

VT 17 Kalahari Thornveld invaded by Karoo (31%), VT 40 False Orange River Broken Veld (21%) (Acocks 1953). LR 32 Kimberley Thorn Bushveld (44%), LR 51 Orange River Nama Karoo (36%) (Low & Rebelo 1996).

Distribution Northern Cape and Free State Provinces: Extends along solitary hills and scattered ridges east of the confluence of the Orange and Vaal Rivers, mainly in the Kimberley and Herbert Districts and west of a line bounded by the western Free State towns of Luckhoff, Petrusburg, Dealesville, Bultfontein and Hertzogville. Altitude 1 000–1 400 m.

Vegetation & Landscape Features Slopes and elevated hills and ridges within plains of mainly SVk 4 Kimberley Thornveld, also in the vicinity of NKu 3 Northern Upper Karoo. Evergreen shrub communities dominated by *Tarchonanthus camphoratus*, *Olea europaea* subsp. *africana*, *Euclea crispa*, *Diospyros lycioides*, *Rhus burchellii* and *Buddleja saligna*. Sheltered, cool sites include trees such as *R. lancea*, *Celtis africana* and *Ziziphus mucronata*. On the footslopes of the dolerite hills, where calcrete-rich soils occur, shrubs and small trees of *Acacia tortilis* and *Z. mucronata* can be dominant.

Geology & Soils A highly fragmented area on Ecca and Dwyka Group sediments and Karoo dolerites as well as on Ventersdorp Supergroup lavas (Allanridge Formation). Extensive dolerite sills which form ridges, and plateaus and slopes of koppies and small escarpments mark the erosion terraces. These dolerite sills cover alternating layers of mudstone and sandstone of sedimentary origin. The Ib land type is typical of these rock- and boulder-covered slopes. Prominent soil forms are the stony Mispah and gravel-rich Glenrosa forms derived from Jurassic dolerite, calcrete-rich soils cover the lowlands (Kimberley and Plooysburg forms).

Climate Summer and autumn rainfall with very dry winters. MAP about 250–450 mm. Frost frequent in winter, especially on bottomlands. Mean monthly maximum and minimum temperatures for Douglas 39.7°C and –4.6°C for January and July, respectively. See also climate diagram for SVk 5 Vaalbos Rocky Shrubland.

Important Taxa Small Trees: *Boscia albitrunca*, *Cussonia paniculata*, *Rhus lancea*. Tall Shrubs: *Euclea crispa* subsp. *crispa* (d), *Olea europaea* subsp. *africana* (d), *Tarchonanthus camphoratus* (d), *Ziziphus mucronata* (d), *Buddleja saligna*, *Cadaba aphylla*, *Diospyros austro-africana*, *D. lycioides* subsp. *lycioides*, *Ehretia rigida* subsp. *rigida*, *Gymnosporia polyacantha*, *Rhigozum obovatum*, *Rhus burchellii*. Low Shrubs: *Asparagus suaveolens*, *Hermannia comosa*, *Lantana rugosa*, *Lycium pilifolium*, *Pentzia globosa*, *Rhus ciliata*. Succulent Shrubs: *Cotyledon orbiculata* var. *orbiculata*, *Crassula nudicaulis*, *Kalanchoe paniculata*, *Lycium cinereum*. Graminoids: *Aristida adscensionis*, *A. congesta*, *Digitaria eriantha* subsp. *eriantha*, *Elionurus muticus*, *Enneapogon scoparius*, *Eragrostis lehmanniana*, *E. obtusa*, *Eustachys paspaloides*, *Fingerhuthia africana*, *Heteropogon contortus*, *Hyparrhenia hirta*, *Stipagrostis uniplumis*, *Themeda triandra*. Herbs: *Chascanum pinnatifidum*, *Harpagophytum procumbens* subsp. *procumbens*, *Hibiscus pusillus*. Geophytic Herbs: *Albuca setosa*, *Cheilanthes eckloniana*, *Haemanthus humilis* subsp. *humilis*, *Pellaea calomelanos*. Succulent Herbs: *Aloe grandidentata*, *Stapelia grandiflora*.

Conservation Least threatened. Target 16%. Less than 2% statutorily conserved in the Vaalbos National Park. Only about 2% already transformed.

Remarks Although similar topography and geology to that of koppies in the broad surrounds of Bloemfontein (Gh 4 Besemkaree Koppies Shrubland and Gh 7 Winburg Grassy Shrubland) in the Grassland Biome, the vegetation of this unit differs considerably in species composition through the occurrence of more arid elements.

References Malan et al. (1998, 2001), Müller (2002).

SVk 6 Schmidtsdrif Thornveld

VT 16 Kalahari Thornveld and Shrub Bushveld (56%) (Acocks 1953). LR 32 Kimberley Thorn Bushveld (89%) (Low & Rebelo 1996).

Distribution Northern Cape, Free State and North-West Provinces: Footslopes and midslopes to the southeast and below the Ghaap Plateau from around Douglas in the southwest via Schmidtsdrif towards Taung in the northeast. A small less typical section is found east of the Ghaap Plateau from Warrenton towards Hertzogville. Altitude 1 000–1 350 m.

Vegetation & Landscape Features Mostly a closed shrubby thornveld dominated by *Acacia mellifera* and *A. tortilis*. Apart from grasses, bulbous and annual herbaceous plant species are also prominent. The vegetation is sometimes very disturbed due to overgrazing by goats and other browsers.

Geology & Soils Most significant are the Dwyka diamictites and Ecca shales of the Karoo Supergroup. Shale and dolomite of the Schmidtsdrif Subgroup (Griqualand West Supergroup) are also present. Surface limestone occurs sporadically. Well-drained, shallow (<0.3 m), stony soil with large angular rocks on the soil surface. A soil-rock complex with Mispah soil form. Land types mainly Ae and Dc.

Climate Summer and autumn rainfall with very dry winters. MAP from about 250 mm in the southwest to about 450 mm in the northeast. Frost frequent in winter. See also climate diagram for SVk 6 Schmidtsdrif Thornveld.

Important Taxa Small Trees: *Acacia mellifera* subsp. *detinens* (d), *A. tortilis* subsp. *heteracantha* (d), *Ficus cordata*, *Ziziphus mucronata*. Tall Shrubs: *Tarchonanthus camphoratus* (d), *Grewia flava*. Low Shrubs: *Aptosimum albomarginatum* (d), *Barleria rigida* (d), *Monechma incanum* (d), *Pentzia incana* (d), *Hermannia affinis*, *H. comosa*, *Ptycholobium biflorum*, *Zygophyllum pubescens*. Semiparasitic Shrub: *Thesium lineatum*. Graminoids: *Aristida meridionalis* (d), *Enneapogon cenchroides* (d), *Eragrostis lehmanniana* (d), *E. obtusa* (d), *Enneapogon desvauxii*. Herbs: *Lepidium bonariense* (d), *Amaranthus praetermissus*, *Heliotropium ciliatum*, *Indigastrum parviflorum*, *Osteospermum muricatum*, *Seddera capensis*, *Stachys hyssopoides*.

Biogeographically Important Taxa (Griqualand West endemics) Low Shrub: *Blepharis marginata*. Succulent Shrub: *Prepodesma orpenii* (endemic genus).

Conservation Least threatened. Target 16%. Only 0.2% statutorily conserved in the Vaalbos National Park. Some 13% already transformed, mainly by cultivation. Erosion is very low to low. Of alien plant taxa, *Prosopis* deserves attention.

References Gubb (1980), Crowe et al. (1981), Bezuidenhout (1994), Smit (2000).

SVk 7 Ghaap Plateau Vaalbosveld

VT 16 Kalahari Thornveld and Shrub Bushveld (74%) (Acocks 1953). LR 33 Kalahari Plateau Bushveld (86%) (Low & Rebelo 1996).

Distribution Northern Cape and North-West Provinces: Flat plateau from around Campbell in the south, east of Danielskuil through Reivilo to around Vryburg in the north. Altitude 1 100–1 500 m.

Vegetation & Landscape Features Flat plateau with well-developed shrub layer with *Tarchonanthus camphoratus* and *Acacia karroo*. Open tree layer has *Olea europaea* subsp. *africana*, *A. tortilis*, *Ziziphus mucronata* and *Rhus lancea*. *Olea* is more important in the southern parts of the unit, while *A. tortilis*, *A. hebeclada* and *A. mellifera* are more important in the north and part of the west of the unit. Much of the south-central part of this unit has remarkably low cover of *Acacia* species for an arid savanna and is dominated by the nonthorny *T. camphoratus*, *R. lancea* and *O. europaea* subsp. *africana*.

Geology & Soils Surface limestone of Tertiary to Recent age, and dolomite and chert of the Campbell Group (Griqualand West Supergroup, Vaalian Erathem) support shallow soils (0.1–0.25 m) of Mispah and Hutton soil forms. Land types mainly Fc with some Ae and Ag.

Climate Summer and autumn rainfall with very dry winters. MAP from about 300 mm in the southwest to about 500 mm in the northeast. Frost frequent to very frequent in winter. Mean monthly maximum and minimum temperatures for Koopmansfontein 36.3°C and –7.5°C for January and July, respectively. Corresponding values for Armoedsvlakte (near Vryburg) 36.6°C and –5.5°C for December and July, respectively. See also climate diagram for SVk 7 Ghaap Plateau Vaalbosveld.

Important Taxa Tall Tree: *Acacia erioloba*. Small Trees: *Acacia mellifera* subsp. *detinens* (d), *Rhus lancea* (d), *Acacia karroo*, *A. tortilis* subsp. *heteracantha*, *Boscia albitrunca*. Tall Shrubs: *Olea*

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Figure 9.77 SVk 7 Ghaap Plateau Vaalbosveld: Open savanna dominated by *Tarchonanthus camphoratus* and *Olea europaea* subsp. *africana* between Papkuil and Campbell, Northern Cape Province.

europaea subsp. *africana* (d), *Rhigozum trichotomum* (d), *Tarchonanthus camphoratus* (d), *Ziziphus mucronata* (d), *Diospyros austro-africana*, *D. pallens*, *Ehretia rigida* subsp. *rigida*, *Euclea crispa* subsp. *ovata*, *Grewia flava*, *Gymnosporia buxifolia*, *Lessertia frutescens*, *Rhus tridactyla*. Low Shrubs: *Acacia hebeclada* subsp. *hebeclada* (d), *Aptosimum procumbens*, *Chrysocoma ciliata*, *Helichrysum zeyheri*, *Hermannia comosa*, *Lantana rugosa*, *Leucas capensis*, *Melolobium microphyllum*, *Peliostomum leucorrhizum*, *Pentzia globosa*, *P. viridis*, *Zygophyllum pubescens*. Succulent Shrubs: *Hertia pallens*, *Lycium cinereum*. Semiparasitic Shrub: *Thesium hystrix*. Woody Climber: *Asparagus africanus*. Graminoids: *Anthephora pubescens* (d), *Cenchrus ciliaris* (d), *Digitaria eriantha* subsp. *eriantha* (d), *Enneapogon scoparius* (d), *Eragrostis lehmanniana* (d), *Schmidtia pappophoroides* (d), *Themeda triandra* (d), *Aristida adscensionis*, *A. congesta*, *A. diffusa*, *Cymbopogon pospischilii*, *Enneapogon cenchroides*, *E. desvauxii*, *Eragrostis echinochloidea*, *E. obtusa*, *E. rigidior*, *E. superba*, *Fingerhuthia africana*, *Heteropogon contortus*, *Sporobolus fimbriatus*, *Stipagrostis uniplumis*, *Tragus racemosus*. Herbs: *Barleria macrostegia*, *Geigeria filifolia*, *G. ornativa*, *Gisekia africana*, *Helichrysum cerastioides*, *Heliotropium ciliatum*, *Hermbstaedtia odorata*, *Hibiscus marlothianus*, *H. pusillus*, *Jamesbrittenia aurantiaca*, *Limeum fenestratum*, *Lippia scaberrima*, *Selago densiflora*, *Vahlia capensis* subsp. *vulgaris*. Succulent Herb: *Aloe grandidentata*.

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Figure 9.78 SVk 8 Kuruman Vaalbosveld: Open savanna dominated by *Tarchonanthus camphoratus* and *Rhus lancea* with a mix of grasses including *Themeda triandra* near Lykso, between Kuruman and Vryburg, North-West Province.

Biogeographically Important Taxa ([GW]Griqualand West endemic, [K]Kalahari endemic, [D]Broadly disjunct distribution) Tall Shrubs: *Lebeckia macrantha*[GW], *Nuxia gracilis*[D]. Low Shrubs: *Blepharis marginata*[GW], *Putterlickia saxatilis*[GW], *Tarchonanthus obovatus*[GW]. Succulent Shrubs: *Euphorbia wilmaniae*[GW], *Prepodesma orpenii*[GW] (endemic genus). Graminoids: *Digitaria polyphylla*[GW], *Panicum kalaharense*[K]. Herbs: *Corchorus pinnatipartitus*[GW], *Helichrysum arenicola*[K]. Succulent Herb: *Orbea knobelii*[K].

Endemic Taxon Herb: *Rennera stellata*.

Conservation Least threatened. Target 16%. None conserved in statutory conservation areas. Only about 1% already transformed. Erosion is very low.

Reference Smit (2000).

SVk 8 Kuruman Vaalbosveld

VT 16 Kalahari Thornveld and Shrub Bushveld (100%) (Acocks 1953). LR 33 Kalahari Plateau Bushveld (74%) (Low & Rebelo 1996).

Distribution North-West and Northern Cape Provinces: East of Kuruman to Lykso, south of Bendell towards Good Hope. Altitude 1 300–1 500 m.

Vegetation & Landscape Features Open tree layer characterised by *Acacia erioloba*, *A. karroo*, *Rhus lancea* and *Ziziphus mucronata*. Shrub layer poorly developed, with *Grewia flava* and *Tarchonanthus camphoratus* and grass layer open, with much bare soil in places.

Geology & Soils Carbonates and chert of the Vaalian Griqualand West Supergroup and Kalahari sediments form flat, rocky, sandy plains with shallow (0.1–0.6 m) red aeolian sands, stony and underlain by rock. Dominant land types Ae and Fc, with Hutton, Clovelly and Mispah soil forms common.

Climate Summer and autumn rainfall with very dry winters. MAP about 350–450 mm. Frost very frequent in winter. See also climate diagram for SVk 8 Kuruman Vaalbosveld.

Important Taxa Tall Tree: *Acacia erioloba* (d). Small Trees: *Acacia karroo* (d), *Ziziphus mucronata* (d), *Rhus lancea*. Tall Shrubs: *Tarchonanthus camphoratus* (d), *Cadaba aphylla*, *Diospyros austro-africana*, *D. lycioides* subsp. *lycioides*, *Grewia flava*, *Gymnosporia buxifolia*. Low Shrubs: *Amphiglossa triflora*, *Anthospermum rigidum* subsp. *pumilum*, *A. rigidum* subsp. *rigidum*, *Helichrysum zeyheri*. Geoxylic Suffrutex: *Elephantorrhiza elephantina*. Succulent Shrub: *Ebracteola wilmaniae*. Herbaceous Climber: *Rhynchosia holosericea*. Graminoids: *Anthephora pubescens* (d), *Aristida meridionalis* (d), *Eragrostis lehmanniana* (d), *Stipagrostis uniplumis* (d), *Aristida stipitata* subsp. *spicata*, *Cymbopogon caesius*, *Digitaria eriantha* subsp. *eriantha*, *Fingerhuthia africana*, *Pogonarthria squarrosa*, *Schmidtia pappophoroides*, *Themeda triandra*, *Tragus koelerioides*. Herbs: *Acrotome inflata*, *Dicoma schinzii*, *Geigeria ornativa*, *Heliotropium strigosum*, *Stachys spathulata*, *Tripteris aghillana*.

Biogeographically Important Taxon (Kalahari endemic) Graminoid: *Anthephora argentea*.

Conservation Least threatened. Target 16%. None conserved in statutory conservation areas. Erosion is very low.

Remark In the dolomite area, sinkholes may be filled with wind-blown sand and occupied by conspicuous dense clumps of *Acacia erioloba*.

Reference Smit (2000).

SVk 9 Kuruman Thornveld

VT 16 Kalahari Thornveld and Shrub Bushveld (98%) (Acocks 1953). LR 30 Kalahari Plains Thorn Bushveld (67%) (Low & Rebelo 1996).

Distribution North-West and Northern Cape Provinces: On flats from the vicinity of Postmasburg and Danielskuil (here west of the Kuruman Hills) in the south extending via Kuruman to Tsineng and Dewar in the north. Altitude 1 100–1 500 m.

Vegetation & Landscape Features Flat rocky plains and some sloping hills with very well-developed, closed shrub layer and well-developed open tree stratum consisting of *Acacia erioloba*.

Geology & Soils Some Campbell Group dolomite and chert and mostly younger, superficial Kalahari Group sediments, with red wind-blown (0.3–1.2 m deep) sand. Locally, rocky pavements are formed in places. Most important land types Ae, Ai, Ag and Ah, with Hutton soil form.

Climate Summer and autumn rainfall with very dry winters. MAP about 300–450 mm. Frost frequent in winter. Mean monthly maximum and minimum temperatures for Kuruman 35.9°C and –3.3°C for January and June, respectively. See also climate diagram for SVk 9 Kuruman Thornveld.

Important Taxa Tall Tree: *Acacia erioloba* (d). Small Trees: *Acacia mellifera* subsp. *detinens* (d), *Boscia albitrunca* (d). Tall Shrubs: *Grewia flava* (d), *Lycium hirsutum* (d), *Tarchonanthus camphoratus* (d), *Gymnosporia buxifolia*. Low Shrubs: *Acacia hebeclada* subsp. *hebeclada* (d), *Monechma divaricatum* (d), *Gnidia polycephala*, *Helichrysum zeyheri*, *Hermannia comosa*, *Pentzia calcarea*, *Plinthus sericeus*. Geoxylic Suffrutex: *Elephantorrhiza elephantina*. Graminoids: *Aristida meridionalis* (d), *A. stipitata* subsp. *stipitata* (d), *Eragrostis lehmanniana* (d), *E. echinochloidea*, *Melinis repens*. Herbs: *Dicoma schinzii*, *Gisekia africana*, *Harpagophytum procumbens* subsp. *procumbens*, *Indigofera daleoides*, *Limeum fenestratum*, *Nolletia ciliaris*, *Seddera capensis*, *Tripteris aghillana*, *Vahlia capensis* subsp. *vulgaris*.

Biogeographically Important Taxa ([GW]Griqualand West endemic, [K]Kalahari endemic, [S]Southernmost distribution in interior of southern Africa) Small Trees: *Acacia luederitzii* var. *luederitzii*[K], *Terminalia sericea*[S]. Tall Shrub: *Acacia haematoxylon*[K]. Low Shrub: *Blepharis marginata*[GW]. Graminoid: *Digitaria polyphylla*[GW]. Herb: *Corchorus pinnatipartitus*[GW].

Endemic Taxon Herb: *Gnaphalium englerianum*.

Conservation Least threatened. Target 16%. None conserved in statutory conservation areas. Only 2% already transformed. Erosion is very low.

Remark Disturbed areas north of Kuruman are characterised by *Aristida adscensionis*, *A. congesta*, *Enneapogon scoparius*, *Geigeria ornativa*, *Melhania rehmanii*, *Rhigozum trichotomum* and *Sericorema remotiflora* and the absence of *Acacia erioloba*, *A. haematoxylon* and *Grewia flava*.

Reference Smit (2000).

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Figure 9.79 SVk 9 Kuruman Thornveld: *Acacia erioloba* trees and the overwhelmingly dominant shrub *Tarchonanthus camphoratus* immediately south of Kuruman at an altitude of 1 415 m.

SVk 10 Kuruman Mountain Bushveld

VT 16 Kalahari Thornveld and Shrub Bushveld (64%) (Acocks 1953). LR 31 Kalahari Mountain Bushveld (57%) (Low & Rebelo 1996).

Distribution Northern Cape and North-West Provinces: From the Asbestos Mountains southwest and northwest of Griekwastad, along the Kuruman Hills north of Danielskuil, passing west of Kuruman town and re-emerging as isolated hills, i.e. Makhubung and the hills around Pomfret in the north. Altitude 1 100–1 800 m.

Vegetation & Landscape Features Rolling hills with generally gentle to moderate slopes and hill pediment areas with an open shrubveld with *Lebeckia macrantha* prominent in places. Grass layer is well developed.

Geology & Soils The Kuruman and Asbestos Hills consist of banded iron formation, with jaspilite, chert and riebeckite-asbestos of the Asbestos Hills Subgroup of the Griqualand West Supergroup (Vaalian). Most common land type Ib, followed by Ae, Ic and Ag. Soils are shallow sandy soils, of the Hutton form.

Climate Summer and autumn rainfall with very dry winters. MAP about 250–500 mm. Frost frequent in winter. The unit corresponds in part to cluster 17 of the 27 in the physio-climatic classification of South Africa's woodland areas with summer rainfall (Fairbanks 2000). See also climate diagram for SVk 10 Kuruman Mountain Bushveld.

Important Taxa Small Tree: *Rhus lancea*. Tall Shrubs: *Diospyros austro-africana*, *Euclea crispa* subsp. *crispa*, *E. undulata*, *Olea europaea* subsp. *africana*, *Rhus pyroides* var. *pyroides*, *R. tridactyla*, *Tarchonanthus camphoratus*, *Tephrosia longipes*. Low Shrubs: *Rhus ciliata* (d), *Amphiglossa triflora*, *Anthospermum rigidum* subsp. *pumilum*, *Gomphocarpus fruticosus* subsp. *fruticosus*, *Helichrysum zeyheri*, *Lantana rugosa*, *Wahlenbergia nodosa*. Succulent Shrubs: *Ebracteola wilmaniae*, *Hertia pallens*. Herbaceous Climber: *Rhynchosia totta*. Graminoids: *Andropogon chinensis* (d), *A. schirensis* (d), *Anthephora pubescens* (d), *Aristida congesta* (d), *Digitaria eriantha* subsp. *eriantha* (d), *Themeda triandra* (d), *Triraphis andropogonoides* (d), *Aristida diffusa*, *Brachiaria nigropedata*, *Bulbostylis burchellii*, *Cymbopogon caesius*, *Diheteropogon amplectens*, *Elionurus muticus*, *Eragrostis chloromelas*, *E. nindensis*, *Eustachys paspaloides*, *Heteropogon contortus*, *Melinis repens*, *Schizachyrium sanguineum*, *Trichoneura grandiglumis*. Herbs: *Dicoma anomala*, *D. schinzii*, *Geigeria ornativa*, *Helichrysum cerastioides*, *Heliotropium strigosum*, *Hibiscus marlothianus*, *Kohautia cynanchica*, *Kyphocarpa angustifolia*. Geophytic Herbs: *Boophone disticha*, *Pellaea calomelanos*.

Biogeographically Important Taxa (Griqualand West endemics) Tall Shrub: *Lebeckia macrantha* (d). Low Shrubs: *Justicia puberula*, *Tarchonanthus obo-*

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Figure 9.80 SVk 10 Kuruman Mountain Bushveld: Open low bushveld with the usually leafless *Lebeckia macrantha* clearly visible at an altitude of approximately 1 680 m near Bretby between Danielskuil and Kuruman.

vatus. Succulent Shrub: *Euphorbia wilmaniae*. Graminoid: *Digitaria polyphylla*. Herb: *Sutera griquensis*.

Endemic Taxon Succulent Shrub: *Euphorbia planiceps*.

Conservation Least threatened. Target 16%. None conserved in statutory conservation areas. Very little transformed. Erosion is very low to low. Some parts in the north are heavily utilised for grazing.

Remarks Many species in this unit are widely distributed to the northeast of the subcontinent and reach their southwestern limit in this unit (e.g. *Andropogon schirensis*). There are distinct floristic differences with the relatively nearby and parallel mountains of the SVk 15 Koranna-Langeberg Mountain Bushveld. For example, *Croton gratissimus* is common in the last mentioned unit but rare in Kuruman Mountain Bushveld. *Lebeckia macrantha* shows just the reverse distributional pattern between these units. A very low form (<0.5 m) of *Acacia hebeclada* is common in the north on Makhubung hill, north of Heuningvlei.

References Smit (2000), Van Wyk & Smith (2001).

SVk 11 Molopo Bushveld

VT 16 Kalahari Thornveld and Shrub Bushveld (100%) (Acocks 1953). LR 30 Kalahari Plains Thorn Bushveld (100%) (Low & Rebelo 1996).

Distribution North-West and Northern Cape Provinces: In the Molopo area from Bray and Werda in the north on the border with Botswana, southwards through Morokweng and Tosca in the east and Vorstershoop to McCarthysrus and Eldorado in the west to Bendell in the south. Altitude 1 000–1 300 m.

Vegetation & Landscape Features Open woodland to a closed shrubland with the trees *Acacia erioloba* and *Boscia albitrunca* and shrubs *Lycium cinereum*, *L. hirsutum* and *Rhigozum trichotomum*. Grass layer is well developed in parts of the northeast, but usually fairly open.

Geology & Soils Red aeolian sand of Recent age with surface calcrete and silcrete. Soils are deep (>1.2 m) and sandy (Hutton and Clovelly soil forms). Land types mainly Ah with a little Fc.

Climate Summer and autumn rainfall with very dry winters. MAP about 250–400 mm. Frost frequent in winter. See also climate diagram for SVk 11 Molopo Bushveld.

Important Taxa Tall Tree: *Acacia erioloba* (d). Small Trees: *Boscia albitrunca* (d), *Terminalia sericea* (d), *Acacia mellifera* subsp. *detinens*. Tall Shrubs: *Lycium hirsutum* (d), *Rhigozum trichotomum* (d), *Grewia flava*, *Lycium villosum*, *Rhus burchellii*. Low Shrubs: *Acacia hebeclada* subsp. *hebeclada*, *Aptosimum albomarginatum*, *A. marlothii*, *Eriocephalus ericoides*, *Monechma divaricatum*, *M. incanum*. Geoxylic Suffrutex: *Elephantorrhiza elephantina*. Herbaceous Climber: *Momordica balsamina*. Graminoids: *Aristida meridionalis* (d), *A. stipitata* subsp. *spicata* (d), *Cenchrus ciliaris* (d), *Eragrostis lehmanniana* (d), *Aristida congesta*, *Eragrostis biflora*, *E. pallens*, *E. rigidior*, *Pogonarthria squarrosa*, *Schmidtia kalahariensis*, *S. pappophoroides*, *Stipagrostis ciliata*, *S. uniplumis*. Herbs: *Acanthosicyos naudinianus*, *Acrotome angustifolia*, *A. inflata*, *Dicoma schinzii*, *Geigeria ornativa*, *Helichrysum cerastioides*, *Hermannia tomentosa*, *Hermbstaedtia fleckii*, *H. linearis*, *Limeum arenicolum*, *L. fenestratum*, *L. viscosum*, *Lotononis platycarpa*, *Senna italica* subsp. *arachoides*, *Sericorema remotiflora*, *Tephrosia purpurea* subsp. *leptostachya*, *Tribulus terrestris*.

Biogeographically Important Taxa (Kalahari endemics) Small Tree: *Acacia luederitzii* var. *luederitzii*. Tall Shrub: *Acacia haematoxylon*. Graminoids: *Anthephora argentea*, *Megaloprotachne albescens*, *Panicum kalaharense*.

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Figure 9.81 SVk 11 Molopo Bushveld: Plains with *Terminalia sericea*, *Boscia albitrunca*, *Acacia erioloba*, *Grewia flava*, *Stipagrostis uniplumis* and *Tribulus zeyheri* subsp. *zeyheri* on Mahakane southwest of Pomfret, Vryburg District in the North-West Province.

Conservation Least threatened. Target 16%. Only 1% statutorily conserved in the Molopo Nature Reserve. More than 1% already transformed. In the Morokweng, Konke and Ewbank regions, intense utilisation has led to encroachment of *Geigeria ornativa*, *Tribulus terrestris* and *Acacia mellifera*, while much *A. erioloba* has been destroyed by fire-wood collection. Erosion is very low.

Remark An extensive unit with increasing diversity of savanna plant species towards the north and northeast.

Reference Smit (2000).

SVk 12 Kathu Bushveld

VT 16 Kalahari Thornveld and Shrub Bushveld (100%) (Acocks 1953). LR 30 Kalahari Plains Thorn Bushveld (86%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Plains from Kathu and Dibeng in the south, through Hotazel, vicinity of Frylinckspan to the Botswana border roughly between Van Zylsrus and McCarthysrus. Altitude 960–1 300 m.

Vegetation & Landscape Features Medium-tall tree layer with *Acacia erioloba* in places, but mostly open and including *Boscia albitrunca* as the prominent trees. Shrub layer generally most important with, for example, *A. mellifera*, *Diospyros lycioides* and *Lycium hirsutum*. Grass layer is variable in cover.

Geology & Soils Aeolian red sand and surface calcrete, deep (>1.2 m) sandy soils of Hutton and Clovelly soil forms. Land types mainly Ah and Ae, with some Ag.

Climate Summer and autumn rainfall with very dry winters. MAP about 220–380 mm. Frost frequent in winter. Mean monthly maximum and minimum temperatures for Sishen 37.0°C and –2.2°C for December and July, respectively. See also climate diagram for SVk 12 Kathu Bushveld.

Important Taxa Tall Tree: *Acacia erioloba* (d). Small Trees: *Acacia mellifera* subsp. *detinens* (d), *Boscia albitrunca* (d), *Terminalia sericea*. Tall Shrubs: *Diospyros lycioides* subsp. *lycioides* (d), *Dichrostachys cinerea*, *Grewia flava*, *Gymnosporia buxifolia*, *Rhigozum brevispinosum*. Low Shrubs: *Aptosimum decumbens*, *Grewia retinervis*, *Nolletia arenosa*, *Sida cordifolia*, *Tragia dioica*. Graminoids: *Aristida meridionalis* (d), *Brachiaria nigropedata* (d), *Centropodia glauca* (d), *Eragrostis lehmanniana* (d), *Schmidtia pappophoroides* (d), *Stipagrostis ciliata* (d), *Aristida congesta*, *Eragrostis biflora*, *E. chloromelas*, *E. heteromera*, *E. pallens*, *Melinis repens*, *Schmidtia kalahariensis*, *Stipagrostis uniplumis*, *Tragus berteronianus*. Herbs: *Acrotome inflata*, *Erlangea misera*, *Gisekia africana*, *Heliotropium ciliatum*, *Hermbstaedtia fleckii*, *H. odorata*, *Limeum fenestratum*, *L. viscosum*, *Lotononis platycarpa*, *Senna italica* subsp. *arachoides*, *Tribulus terrestris*.

Biogeographically Important Taxa (Kalahari endemics) Small Tree: *Acacia luederitzii* var. *luederitzii*. Graminoids: *Anthephora argentea*, *Megaloprotachne albescens*, *Panicum kalaharense*. Herb: *Neuradopsis bechuanensis*.

Conservation Least threatened. Target 16%. None conserved in statutory conservation areas. More than 1% already transformed, including the iron ore mining locality at Sishen, one of the biggest open-cast mines in the world. Erosion is very low.

Remark One of the most strikingly dominant areas of fairly tall *Acacia erioloba* is centred on the town of Kathu, which was built around many of these trees.

Reference Smit (2000).

SVk 13 Olifantshoek Plains Thornveld

VT 17 Kalahari Thornveld invaded by Karoo (49%), VT 16 Kalahari Thornveld and Shrub Bushveld (48%) (Acocks 1953). LR 31 Kalahari Mountain Bushveld (62%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Plains including most of the pediment areas of the Korannaberg, Langeberg and Asbestos Mountains as well as those of some ridges to the west of the Langeberg. From the vicinity of Sonstraal in the north, past Olifantshoek to areas north of Niekerkshoop between Volop and Griekwastad in the south. Also from Griekwastad northwards to the flats west of the Lime Acres area. Altitude 1 000–1 500 m.

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Figure 9.82 SVk 12 Kathu Bushveld: Open savanna dominated by *Acacia erioloba*, *A. mellifera* and *Grewia flava* with low cover of *Stipagrostis ciliata* against the red sand east of Oupos, in the Kuruman District north of Kathu.

Vegetation & Landscape Features A very wide and diverse unit on plains with usually open tree and shrub layers with, for example, *Acacia luederitzii*, *Boscia albitrunca* and *Rhus tenuinervis* and with a usually sparse grass layer.

Geology & Soils Red aeolian sand of Tertiary to Recent age (Kalahari Group) with silcrete and calcrete and some andesitic and basaltic lava of the Griqualand West Supergroup. Hutton soil forms, deeper than 1.2 m, on the overwhelmingly dominant Ae and to a far lesser extent Ah land types.

Climate Summer and autumn rainfall with very dry winters. MAP about 200–350 mm in the east. Frost frequent in winter. See also climate diagram for SVk 13 Olifantshoek Plains Thornveld.

Important Taxa Tall Tree: *Acacia erioloba*. Small Trees: *Boscia albitrunca* (d), *Acacia mellifera* subsp. *detinens*, *Terminalia sericea*. Tall Shrubs: *Lessertia*

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Figure 9.83 SVk 13 Olifantshoek Plains Thornveld: Very open shrubland with *Boscia albitrunca, Acacia luderitzii, Schmidtia pappophoroides* and *S. kalahariensis* in the western part of this unit.

frutescens, *Lycium hirsutum*, *Rhigozum obovatum*, *Rhus tridactyla, Tarchonanthus camphoratus*. Low Shrubs: *Aptosimum procumbens*, *Grewia retinervis*, *Hoffmannseggia burchellii*, *Lycium pilifolium*, *Solanum tomentosum*. Succulent Shrubs: *Lycium cinereum*, *Talinum caffrum*. Graminoids: *Schmidtia pappophoroides* (d), *Stipagrostis uniplumis* (d), *Aristida congesta*, *Brachiaria serrata*, *Digitaria eriantha* subsp. *eriantha*, *Melinis repens*. Herbs: *Acanthosicyos naudinianus*, *Gisekia pharnacioides*, *Hermannia tomentosa*, *Ipomoea magnusiana*, *Oxygonum delagoense*, *Pollichia campestris*, *Tephrosia purpurea* subsp. *leptostachya*. Succulent Herb: *Piaranthus decipiens*. Geoxylic Suffrutex: *Elephantorrhiza elephantina*.

Biogeographically Important Taxa ([GW]Griqualand West endemic, [K]Kalahari endemic) Small Tree: *Acacia luederitzii* var. *luederitzii*[K] (d). Tall Shrub: *Lebeckia macrantha*[GW]. Low Shrubs: *Hermannia burchellii*[K], *Justicia puberula*[GW], *Putterlickia saxatilis*[GW], *Tarchonanthus obovatus*[GW]. Graminoid: *Anthephora argentea*[K]. Herb: *Sutera griquensis*[GW].

Endemic Taxon Low Shrub: *Amphiglossa tecta*.

Conservation Least threatened. Target 16%. Only 0.3% statutorily conserved in the Witsand Nature Reserve. Only about 1% of the area has been transformed and erosion is very low.

Reference Smit (2000).

SVk 14 Postmasburg Thornveld

VT 17 Kalahari Thornveld invaded by Karoo (57%) (Acocks 1953). LR 31 Kalahari Mountain Bushveld (64%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Limited area around Postmasburg along the short valley of the Groenwaterspruit to the northeast and southwest, west to Bermolli and around Heuningkrans. Altitude 1 180–1 440 m.

Vegetation & Landscape Features Flats surrounded by mountains supporting open, shrubby thornveld characterised by a dense shrub layer and often lacking a tree layer; the grass layer is very sparse. Shrubs are generally low and with a karroid affinity.

Geology & Soils Red aeolian sand of the Kalahari Group overlying the volcanics and sediments of the Griqualand West Supergroup that outcrop in places. Deep soils are of the Hutton form. Dominant land type Ag.

Climate Summer and autumn rainfall with very dry winters. MAP about 250–350 mm. Frost frequent in winter. See also climate diagram for SVk 14 Postmasburg Thornveld.

Important Taxa Tall Tree: *Acacia erioloba* (d). Small Trees: *Acacia karroo* (d), *A. tortilis* subsp. *heteracantha* (d), *Rhus lancea* (d), *Ziziphus mucronata* (d). Tall Shrubs: *Rhus tridactyla* (d), *Diospyros lycioides* subsp. *lycioides*, *Ehretia rigida* subsp. *rigida*, *Grewia flava*, *Tarchonanthus camphoratus*. Low Shrubs: *Acacia hebeclada* subsp. *hebeclada* (d), *Felicia muricata*, *Gomphocarpus fruticosus* subsp. *fruticosus*, *Lantana rugosa*, *Melolobium microphyllum*, *Sutera halimifolia*. Succulent Shrubs: *Kalanchoe rotundifolia*, *Lycium cinereum*. Graminoids: *Digitaria eriantha* subsp. *eriantha* (d), *Enneapogon scoparius* (d), *Eragrostis lehmanniana* (d), *Aristida adscensionis*, *A. congesta*, *A. diffusa*, *Eragrostis superba*, *Heteropogon contortus*, *Melinis repens*, *Schmidtia pappophoroides*, *Stipagrostis uniplumis*. Herbs: *Dicoma anomala*, *Geigeria filifolia*, *G. ornativa*, *Hibiscus pusillus*, *Jamesbrittenia aurantiaca*, *Selago densiflora*, *Tripteris aghillana*. Geophytic Herb: *Boophone disticha*.

Biogeographically Important Taxa (Griqualand West endemics) Succulent Shrub: *Euphorbia bergii*. Graminoid: *Digitaria polyphylla*.

Conservation Least threatened. Target 16%. None of the unit is conserved in statutory conservation areas, but very little has been transformed. Erosion is very low.

Remark In contrast to eastern parts of the unit, *Tarchonanthus camphoratus* is conspicuously absent in the western parts.

Reference Smit (2000).

SVk 15 Koranna-Langeberg Mountain Bushveld

VT 16 Kalahari Thornveld and Shrub Bushveld (91%) (Acocks 1953). LR 31 Kalahari Mountain Bushveld (67%) (Low & Rebelo 1996).

Distribution Northern Cape Province: From the Tswalu Kalahari Reserve at the northern tip of the Korannaberg southwards in the form of multiple ridges to the Langeberg west of Olifantshoek and southwards along the Langeberg and some parallel ridges, to ridges in the vicinity of Volop. Also some ridges to the west of the Langeberg. Altitude 1 000–1 836 m at highest point.

Vegetation & Landscape Features Rugged mountains and steep slopes in parts of the Korannaberg but with few cliffs in the Langeberg to the south. Generally supporting open shrubland with moderately open grass cover. *Croton gratissimus* common in places, becoming particularly diminutive south of the Langeberg.

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Figure 9.84 SVk 15 Koranna-Langeberg Mountain Bushveld: Shrubland on rocky slope with *Croton gratissimus* and *Tarchonanthus camphoratus* shrubs close to Olifantshoek, Northern Cape Province.

Geology & Soils The geology of the Korannaberg and Langeberg Mountains consists of quartzite, greywacke and lenses of hematite of the Olifantshoek Supergroup (Mokolian Erathem). The soils consist of very rocky, shallow sands. Land types mainly Ic, with some Ae.

Climate Summer and autumn rainfall with very dry winters. MAP about 180–380 mm. Frost frequent in winter. See also climate diagram for SVk 15 Koranna-Langeberg Mountain Bushveld.

Important Taxa Small Trees: *Acacia mellifera* subsp. *detinens* (d), *Boscia albitrunca*, *Ficus cordata*, *Maytenus undata*. Tall Shrubs: *Ehretia rigida* subsp. *rigida*, *Euclea undulata*, *Grewia flava*, *Hibiscus micranthus*, *Rhigozum obovatum*, *Rhus burchellii*, *Tarchonanthus camphoratus*, *Tephrosia longipes*. Low Shrubs: *Croton gratissimus* (d), *Artemisia afra*, *Felicia muricata*, *Indigofera poliotes*, *Jamesbrittenia albiflora*, *Leucas capensis*, *Lophiocarpus polystachyus*, *Melhania prostrata*, *Nolletia arenosa*, *Pegolettia retrofracta*, *Psiadia punctulata*. Succulent Shrubs: *Aloe hereroensis* var. *hereroensis*, *Euphorbia avasmontana*, *E. rectirama*. Semiparasitic Shrub: *Thesium hystrix*. Woody Climber: *Putterlickia pyracantha*. Woody Succulent Climber: *Sarcostemma viminale* (d). Graminoids: *Aristida diffusa* (d), *Eragrostis curvula* (d), *Brachiaria nigropedata*, *Cenchrus ciliaris*, *Digitaria eriantha* subsp. *eriantha*, *Heteropogon contortus*, *Stipagrostis uniplumis*. Herb: *Ceratotheca triloba*. Geophytic Herbs: *Boophone disticha*, *Cheilanthes hirta*, *Pellaea calomelanos*, *Sansevieria aethiopica*.

Biogeographically Important Taxa (Griqualand West endemics) Low Shrub: *Justicia puberula*. Graminoid: *Digitaria polyphylla*.

Conservation Least threatened. Target 16%. None conserved in statutory conservation areas but partly conserved in private reserves such as the Tswalu Kalahari Reserve. Virtually none of the area is transformed. Erosion is very low.

Remark This unit forms the first, almost unbroken, mountain barrier to the east of the Kalahari on the Gordonia plains.

References Smit (2000), Van Wyk & Smith (2001).

SVk 16 Gordonia Plains Shrubland

VT 16 Kalahari Thornveld and Shrub Bushveld (100%) (Acocks 1953). LR 28 Shrubby Kalahari Dune Bushveld (81%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Broad north-south band on flats west of the Korannaberg and Langeberg Mountains (and of their western pediment) and east of the main Kalahari duneveld area (for example at Pearson's Hunt). From Van Zylsrus in the north to southwest of Witsand in the south. Also as a number of isolated patches embedded in the duneveld area between the Auob and Nossob Rivers in the Kgalagadi Transfrontier Park as well as the valley containing Groot and Klein Mier south of the park. Altitude 900–1 250 m.

Vegetation & Landscape Features Plains with open grassland with occasional shrubs *Rhigozum trichotomum* and *Grewia flava*, sometimes including *Acacia haematoxylon* and scattered individuals of *A. erioloba*. The area has virtually no dunes.

Geology & Soils Aeolian sand, underlain by calcrete of the Kalahari Group, deep, loose, sandy soils of the Namib soil form on the flat plains. Land types mainly Ah and Af with a little Ae.

Climate Summer and autumn rainfall with very dry winters. MAP about 180–280 mm. Frost frequent in winter. See also climate diagram for SVk 16 Gordonia Plains Shrubland.

Important Taxa Tall Tree: *Acacia erioloba* (d). Small Tree: *Acacia mellifera* subsp. *detinens*. Tall Shrubs: *Grewia flava* (d), *Rhigozum trichotomum* (d). Low Shrubs: *Jatropha erythro-*

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Figure 9.85 SVk 16 Gordonia Plains Shrubland: Open shrubland dominated by *Rhigozum trichotomum* and *Aristida meridionalis* with a solitary *Acacia haematoxylon* tree on Goedemoed between Olifantshoek and Upington.

poda, *Plinthus sericeus*, *Requienia sphaerosperma*. Geoxylic Suffrutex: *Elephantorrhiza elephantina*. Semiparasitic Shrub: *Thesium lineatum*. Herbaceous Climber: *Merremia tridentata*. Graminoids: *Aristida meridionalis* (d), *Centropodia glauca* (d), *Eragrostis lehmanniana* (d), *Schmidtia kalahariensis* (d), *Brachiaria glomerata*, *Bulbostylis hispidula*, *Eragrostis pallens*, *Stipagrostis uniplumis*. Herbs: *Acanthosicyos naudinianus*, *Cucumis africanus*, *Dicoma capensis*, *Harpagophytum procumbens* subsp. *procumbens*, *Heliotropium ciliatum*, *Hermannia tomentosa*, *Ipomoea hackeliana*, *Limeum argute-carinatum*, *Oxygonum dregeanum* subsp. *canescens* var. *canescens*, *Senna italica* subsp. *arachoides*, *Sericorema remotiflora*.

Biogeographically Important Taxa (Kalahari endemics) Tall Shrub: *Acacia haematoxylon*. Low Shrub: *Hermannia burchellii*. Graminoid: *Anthephora argentea*.

Conservation Least threatened. Target 16%. Some 9% statutorily conserved in the Kgalagadi Transfrontier Park. Very little of the area is transformed and erosion is very low.

References Leistner (1967), Leistner & Werger (1973), Werger & Leistner (1975), Werger (1978b), Lubbinge (1998).

Kalahari Duneveld

SVkd 1 Gordonia Duneveld

VT 16 Kalahari Thornveld and Shrub Bushveld (91%) (Acocks 1953). LR 28 Shrubby Kalahari Dune Bushveld (65%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Areas with dunes comprising the largest part of the South African side of the Kgalagadi Transfrontier Park. South of the Molopo River border with Botswana (west of Van Zylsrus), interleaving with NKb 5 Kalahari Karroid Shrubland in the west (south of Rietfontein to the Orange River area) and in the south (around Upington and north of Groblershoop). Also occurs as a number of loose dune cordons south of the Orange River near Keimoes and between Upington and Putsonderwater. Eastern boundary is found at the longitude of Pearson's Hunt, but with outliers near Niekerkshoop in the southeast and Floradora in the northeast. Altitude 800–1 200 m.

Vegetation & Landscape Features Parallel dunes about 3–8 m above the plains. Open shrubland with ridges of grassland dominated by *Stipagrostis amabilis* on the dune crests and *Acacia haematoxylon* on the dune slopes, also with *A. mellifera* on lower slopes and *Rhigozum trichotomum* in the interdune straaten.

Geology & Soils Aeolian sand underlain by superficial silcretes and calcretes of the Cenozoic Kalahari Group. Fixed parallel sand dunes, with Af land type almost exclusively.

Climate Summer and autumn rainfall with very dry winters. MAP about 120–260 mm. Frost fairly frequent to frequent in winter. Mean monthly maximum and minimum temperatures for Vrouenspan 41.5°C and –4.0°C for December and July, respectively. See also climate diagram for SVkd 1 Gordonia Duneveld.

Important Taxa Small Tree: *Acacia mellifera* subsp. *detinens* (d). Tall Shrubs: *Grewia flava* (d), *Rhigozum trichotomum* (d). Low Shrubs: *Aptosimum albomarginatum*, *Monechma incanum*, *Requienia sphaerosperma*. Succulent Shrubs: *Lycium bosciifolium*, *L. pumilum*, *Talinum caffrum*. Graminoids: *Schmidtia kalahariensis* (d), *Brachiaria glomerata*, *Bulbostylis hispidula*, *Centropodia glauca*, *Eragrostis lehmanniana*, *Stipagrostis ciliata*, *S. obtusa*, *S. uniplumis*. Herbs: *Hermbstaedtia fleckii* (d), *Acanthosicyos naudinianus*, *Hermannia tomentosa*, *Limeum arenicolum*, *L. argute-carinatum*, *Oxygonum dregeanum* subsp. *canescens* var. *canescens*, *Sericorema remotiflora*, *Sesamum triphyllum*, *Tribulus zeyheri*.

Biogeographically Important Taxa (Kalahari endemics) Tall Shrub: *Acacia haematoxylon* (d). Graminoids: *Stipagrostis amabilis* (d), *Anthephora argentea*, *Megaloprotachne albescens*. Herbs: *Helichrysum arenicola*, *Kohautia ramosissima*, *Neuradopsis austro-africana*.

Conservation Least threatened. Target 16%. Some 14% statutorily conserved in the Kgalagadi Transfrontier Park. Very little transformed. Generally low erosion, but some areas with spectacular destabilisation of normally vegetated dunes (through local overstocking) favoured by photographers. Erosion is normally very low.

Remarks The unit extends into Namibia to a large extent (Leistner 1967) and very little into Botswana. Only degenerates into semimobile dunes, where heavily disturbed through intense grazing pressure.

References Leistner (1967), Bothma & De Graaff (1973), Leistner & Werger (1973), Werger & Leistner (1975), Werger (1978b), Skarpe (1986), Lubbinge (1998).

D. Mucina

Figure 9.86 SVkd 1 Gordonia Duneveld: Sparse dune shrubland with *Acacia haematoxylon* (the silvery bush on the slopes) and *Stipagrostis amabilis* (the grass on the dune ridge) in the valley of the Auob River in the Kgalagadi Transfrontier Park.

SVkd 2 Gordonia Kameeldoring Bushveld

VT 16 Kalahari Thornveld and Shrub Bushveld (100%) (Acocks 1953). LR 28 Shrubby Kalahari Dune Bushveld (82%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Duneveld along the northern side of the Auob River from Mata Mata to about Gemsbokplein, and western side of the Nossob River from about Kaspersdraai to St John's Dam in the Kgalagadi Transfrontier Park. A few isolated occurrences between the Auob and Nossob

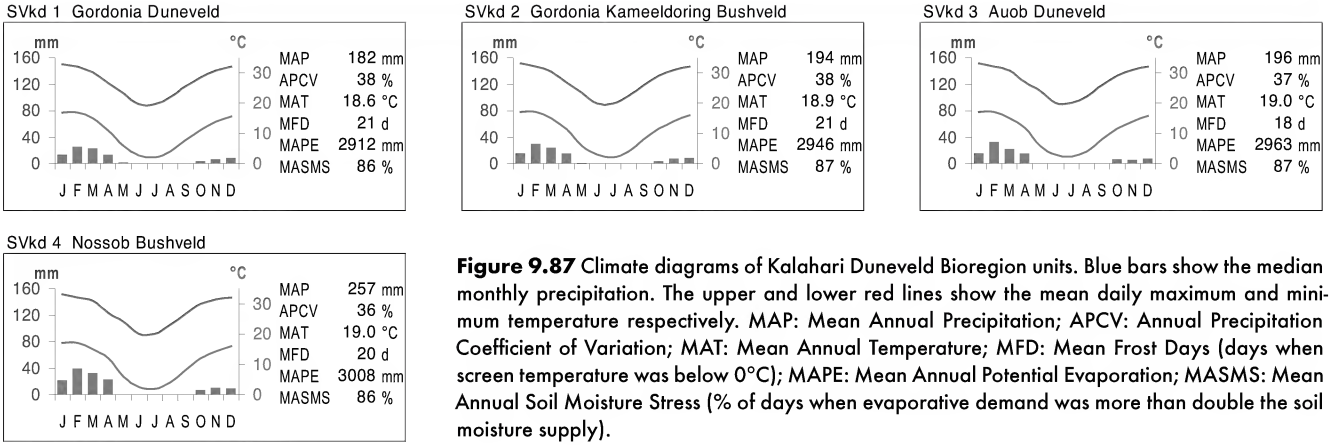

Figure 9.87 Climate diagrams of Kalahari Duneveld Bioregion units. Blue bars show the median monthly precipitation. The upper and lower red lines show the mean daily maximum and minimum temperature respectively. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days (days when screen temperature was below 0°C); MAPE: Mean Annual Potential Evaporation; MASMS: Mean Annual Soil Moisture Stress (% of days when evaporative demand was more than double the soil moisture supply).

Rivers such as around Seven Pans. Also found in marginal area south of the Kuruman River near Eensaam Kasteel. Altitude 920–1 040 m.

Vegetation & Landscape Features On the dune slopes and dune straaten with well-developed tree layer, dominated by *Acacia erioloba* and *Boscia albitrunca* and shrub layer with *A. haematoxylon*, *A. mellifera* and *Rhigozum trichotomum*. Grass layer is very scanty.

Geology & Soils Aeolian undulating sand dunes underlain by calcrete, deep, loose, sandy soil of the Namib soil form. Land type Af.

Climate Summer and autumn rainfall with very dry winters. MAP about 150–250 mm. Frost fairly frequent to frequent in winter. Mean monthly maximum and minimum temperatures for Mata Mata are 40.0°C and –6.8°C for December and June, respectively. See also climate diagram for SVkd 2 Gordonia Kameeldoring Bushveld.

Important Taxa Tall Tree: *Acacia erioloba* (d). Small Trees: *Acacia mellifera* subsp. *detinens* (d), *Boscia albitrunca* (d). Tall Shrubs: *Rhigozum trichotomum* (d), *Ehretia rigida* subsp. *rigida*, *Grewia flava*, *Lycium villosum*, *Rhus tenuinervis*. Low Shrubs: *Aptosimum albomarginatum*, *Jatropha erythropoda*, *Plinthus sericeus*, *Requienia sphaerosperma*. Graminoids: *Aristida meridionalis* (d), *Centropodia glauca* (d), *Eragrostis lehmanniana* (d), *Schmidtia kalahariensis* (d), *Stipagrostis ciliata* (d), *Brachiaria glomerata*, *Stipagrostis obtusa*, *S. uniplumis*. Herbs: *Acanthosicyos naudinianus*, *Hermannia tomentosa*, *Limeum arenicolum*, *Senna italica* subsp. *arachoides*, *Tribulus zeyheri*.

Biogeographically Important Taxa (Kalahari endemics) Tall Shrub: *Acacia haematoxylon* (d). Succulent Herbs: *Orbea knobelii*, *Tridentea marientalensis* subsp. *marientalensis*.

Conservation Least threatened. Target 16%. Some 38% statutorily conserved in the Kgalagadi Transfrontier Park. Very little transformed and showing generally little surface erosion.

References Leistner (1967), Leistner & Werger (1973), Werger & Leistner (1975), Lubbinge (1998).

SVkd 3 Auob Duneveld

VT 16 Kalahari Thornveld and Shrub Bushveld (100%) (Acocks 1953). LR 28 Shrubby Kalahari Dune Bushveld (99%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Belt of duneveld south of the Auob River from Mata Mata to Twee Rivieren within the Kgalagadi Transfrontier Park as well as in the northern Mier area. Found also in the area between the Auob and Nossob Rivers near their confluence as well as small areas around the confluences of the Nossob, Molopo and Kuruman Rivers. Altitude 880–1 040 m.

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Figure 9.88 SVkd 2 Gordonia Kameeldoring Bushveld: Interdune sandy area dominated by *Acacia erioloba* and, in the foreground, *Rhigozum trichotomum* between Nu-Quap and Craig Lockhardt about 5 km from the bed of the Auob River in the Kgalagadi Transfrontier Park, Northern Cape Province.

Vegetation & Landscape Features Open shrubland with low shrub layer dominated by *Acacia haematoxylon*, *A. mellifera* and *Rhigozum trichotomum*. Trees of *A. erioloba* and *Boscia albitrunca* are widely scattered and grass layer is scanty.

Geology & Soils Deep aeolian sand forming undulating dunes, with outcrops of calcrete, Namib soil form. Shallow soils on calcrete outcrops often with Clovelly soil form. Land type Af.

Climate Summer and autumn rainfall with very dry winters. MAP about 150–250 mm. Frost fairly frequent to frequent

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Figure 9.89 SVkd 3 Auob Duneveld: Open shrubland with *Boscia albitrunca* and *Stipagrotis amabilis* in the foreground on the crest of a dune near Kielie Krankie, Kgalagadi Transfrontier Park, Northern Cape.

in winter. Mean monthly maximum and minimum temperatures for Twee Rivieren 40.6°C and –6.0°C for December and July, respectively. See also climate diagram for SVkd 3 Auob Duneveld.

Important Taxa Tall Tree: *Acacia erioloba*. Small Trees: *Acacia mellifera* subsp. *detinens* (d), *Boscia albitrunca*. Tall Shrubs: *Rhigozum trichotomum* (d), *Grewia flava*. Low Shrub: *Requienia sphaerosperma*. Graminoids: *Schmidtia kalahariensis* (d), *Stipagrostis ciliata* (d), *S. uniplumis* (d), *Brachiaria glomerata*, *Bulbostylis hispidula*, *Centropodia glauca*, *Eragrostis trichophora*. Herbs: *Acanthosicyos naudinianus*, *Acrotome angustifolia*, *Hermannia tomentosa*, *Limeum arenicolum*, *Sesamum triphyllum*.

Biogeographically Important Taxa (Kalahari endemics) Tall Shrub: *Acacia haematoxylon* (d). Low Shrub: *Hermannia burchellii*. Graminoid: *Stipagrostis amabilis* (d).

Conservation Least threatened. Target 16%. Some 57% statutorily conserved in the Kgalagadi Transfrontier Park. Erosion is very low.

References Leistner (1967), Leistner & Werger (1973), Werger & Leistner (1975), Lubbinge (1998).

SVkd 4 Nossob Bushveld

VT 16 Kalahari Thornveld and Shrub Bushveld (95%) (Acocks 1953). LR 27 Thorny Kalahari Dune Bushveld (83%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Strip of duneveld west of the Nossob River from Nossob Camp area to Union's End as well as some patches (for example in the vicinity of the waterpoint of Dankbaar) in the far northern parts of the Kgalagadi Transfrontier Park. Altitude 980–1 120 m.

Vegetation & Landscape Features Open bushveld on plains, with relatively tall (for the southern Kalahari) tree layer with *Acacia erioloba*, *A. luederitzii* and *Boscia albitrunca* and grass layer with higher cover than towards the south.

Geology & Soils Aeolian sand of the Kalahari forming undulating dunes. Soil of the Namib soil form. Dominant land type Af.

Climate Summer and autumn rainfall with very dry winters. MAP about 200–300 mm. Frost fairly frequent to frequent in winter. Mean monthly maximum and minimum temperatures for Nossob Rest Camp 39.9°C and –6.2°C for December and July, respectively. See also climate diagram for SVkd 4 Nossob Bushveld.

Important Taxa Tall Tree: *Acacia erioloba* (d). Small Trees: *Boscia albitrunca* (d), *Acacia mellifera* subsp. *detinens*. Tall Shrubs: *Grewia flava*, *Rhus tenuinervis*. Low Shrub: *Plinthus sericeus*. Graminoids: *Schmidtia kalahariensis* (d), *Stipagrostis uniplumis* (d), *Centropodia glauca*, *Eragrostis biflora*. Herbs: *Hermbstaedtia fleckii* (d), *Acanthosicyos naudinianus*, *Pollichia campestris*.

Biogeographically Important Taxa ([K]Kalahari endemic, [D]Southwestern distribution limit in South Africa) Small Trees: *Acacia luederitzii* var. *luederitzii*[K] (d), *Albizia anthelmintica*[D]. Herb: *Neuradopsis austro-africana*[K].

Conservation Least threatened. Target 16%. All of the unit is statutorily conserved in the Kgalagadi Transfrontier Park and remains virtually untransformed. Erosion is very low.

Remark This is the southernmost part of the unit, which is more widely distributed in the neighbouring Botswana and Namibia.

References Leistner & Werger (1973), Werger & Leistner (1975), Van Rooyen et al. (1990), Lubbinge (1998).

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Figure 9.90 SVkd 4 Nossob Bushveld: *Albizia anthelmintica* trees with *Acacia mellifera* shrubs on a large dune between Union's End and Gharagab in the Kgalagadi Transfrontier Park, Northern Cape.

8. Credits

Most of the introductory sections were written by M.C. Rutherford (sections 1, 2.1 (main part), 3.2, 3.3, 4, 5 & 6), with 2.2 by R.A. Ward, 2.3 by F. Ellis, 3.1 by L. Scott and the climate systems part of 2.1 by L. Mucina.

The mapping concepts within the Kalahari bioregions (SVk and SVkd) are based on original mapping by J.H.L. Smit, J.-W. Lubbinge and N. van Rooyen. The detailed legend of the original map was simplified by M.C. Rutherford and L. Mucina after consultation with G.J. Bredenkamp, J.H.L. Smit and H. Bezuidenhout. The southernmost parts of the units within SVk were mapped by M.C. Rutherford, L. Mucina, H. Bezuidenhout and P.J. du Preez.

The areas of the Central Bushveld, Mopane and Lowveld Bioregions were originally mapped for the project by G.J. Bredenkamp, assisted by W.H. de Frey and R.A.J. Robesson (both GIS) using concepts of G.J. Bredenkamp. Later, some of the original concepts in Mpumalanga, southern parts of Limpopo Province, Gauteng and eastern North-West Province were modified by M.C. Lötter (assisted by J.E. Burrows and S. Williamson). These changes included introduction of new units (SVcb 6 (with D.B. Hoare), 12, 14, 16, 25, 26 & SVl 7 & 13). Other new units that were introduced were SVcb 10 by D.B. Hoare, SVcb 22 by M.C. Rutherford and L. Mucina (with shape and position supplied by E. van Wyk), SVcb 24 by P.J.D. Winter and SVl 7 by M.C. Rutherford, L. Mucina and P.J.D. Winter. The sand vegetation of the northern lowveld was split into SVl 1 & 2 by L. Mucina, M.C. Lötter and M.C. Rutherford. The boundaries of most of the earlier mapped units were substantially revised (but with relatively little change to the remaining eight units, namely SVcb 5, 8, 9, 21, 23, SVmp 4, SVl 4 & SVl 15) by M.C. Lötter in many areas as well as by D.B. Hoare in Gauteng, M.C. Rutherford, especially in North-West and Limpopo Provinces, and R.J. Scholes on the Blouberg in Limpopo Province. In the Mopane Bioregion, all units, except SVmp 4, were subdivided and boundaries revised by F. Siebert & M.C. Rutherford.

The current mapping concepts covering the eastern areas of the Lowveld are rooted in Gertenbach's (1983b) 'landscapes', which have been simplified for the purpose of our map by M.C. Rutherford, L. Mucina, M.C. Lötter and F. Siebert, also in consultation with N. Zambatis and H.C. Eckhardt (both who provided the original GIS coverage of Gertenbach's landscapes and discussed the conceptual issues regarding the mapping units). The savanna mapping units of Swaziland were originally derived from an unpublished map of Swaziland by L. Dobson after reconciling the units with those across the border with South Africa. This reconciliation as well as the modification of the boundaries of these entities was done by M.C. Lötter, M.C. Rutherford and L. Mucina. The savanna units recognised for KwaZulu-Natal are the result of co-operation between K.G.T. Camp, R.G. Bennett (GIS), L. Mucina, M.C. Rutherford, C.R. Scott-Shaw, P.S. Goodman, C. Oellermann (GIS) and W.S. Matthews (in Maputaland). The boundaries were derived from the original BRGs (and lower units as defined in the map of Camp (1999a, b, c, d, e), after a series of fusions and some splitting of the original Camp's BRGs. An unpublished map by Smith (2001) was put at our disposal by Ezemvelo KZN Wildlife and was used in part for the spatial definition of some units in Maputaland. The coverage of some subescarpment (SVs) units in the Eastern Cape comes from an original contribution of D.B. Hoare, modified by M.C. Rutherford and L. Mucina, also based on information from Vlok & Euston-Brown (2002).

All Geographical Information Systems (GIS) changes on the map not specifically attributed by name above were made by L.W. Powrie. He also collated and managed all GIS changes to the map.

M.C. Rutherford contributed the descriptions of SVcb 2, 5, 9 & SVl 6 (all with G.J. Bredenkamp), SVcb 4 (with G.J. Bredenkamp and L. Mucina), of SVcb 17 & 19 (both with G.J. Bredenkamp and B.J. Henning), of SVcb 18, 20 & 23 (all with G.J. Bredenkamp and T.H. Mostert), of SVl 1 (with L. Mucina and G.J. Bredenkamp), SVl 3 (with G.J. Bredenkamp and C.E. Venter), SVl 8 & 9 (with M.C. Lötter and J.E. Burrows), SVk 7, 10, 12, 15, 16 & SVkd 1 (all with J.H.L. Smit).

M.C. Lötter contributed the descriptions of SVcb 1, 3 & 12 (all with T.H. Mostert, G.J. Bredenkamp and M.C. Rutherford), of SVcb 6, 13 & 14 (all with M.C. Rutherford), of SVcb 15 (with M.C. Rutherford, G.J. Bredenkamp and B.J. Henning), of SVcb 16 (with M.C. Rutherford, L. Mucina and G.J. Bredenkamp), of SVcb 25 & SVl 7 (both with M.C. Rutherford and J.E. Burrows), of SVcb 26 (with M.C. Rutherford, J.E. Burrows and P.J.D. Winter), of SVl 5 (with M.C. Rutherford, G.J. Bredenkamp, C.E. Venter and F. Siebert), of SVl 10, 11 & 12 (all with M.C. Rutherford, J.E. Burrows and E. Schmidt), of SVl 13 (with S. Williamson and M.C. Rutherford) and of SVl 4 & 14 (with M.C. Rutherford, G.J. Bredenkamp and C.E. Venter).

L. Mucina contributed the descriptions of SVcb 22 (with M.C. Rutherford and P.J.H. Hurter), of SVl 2 (with M.C. Lötter and M.C. Rutherford), of SVl 15 (with M.C. Rutherford), of SVl 16 (with W.S. Matthews, M.C. Lötter, J.E. Burrows, E. Schmidt, C.R. Scott-Shaw and M.C. Rutherford), of SVl 17 (with M.C. Rutherford and C.R. Scott-Shaw), of SVl 18 (with W.S. Matthews and M.C. Rutherford), of SVl 22 & 23 (both with C.R. Scott-Shaw and M.C. Rutherford), of SVl 24 (with C.R. Scott-Shaw), of SVs 1–3 (with K.G.T. Camp and M.C. Rutherford), of SVs 4 (with K.G.T. Camp, D.B. Hoare and M.C. Rutherford) and SVs 6 (with D.B. Hoare, K.G.T. Camp and M.C. Rutherford).

J.H.L. Smit contributed the descriptions of SVk 1–4 (with G.J. Bredenkamp and M.C. Rutherford), and of SVk 8, 9, 11, 13, 14 & SVkd 2 & 3 (all with M.C. Rutherford). F. Siebert contributed the descriptions of SVmp 1–8 (all with M.C. Rutherford). P.S. Goodman contributed the descriptions of SVl 19–21 (with M.C. Rutherford). D.B. Hoare contributed the descriptions of SVs 7 and SVcb 7 (with M.C. Rutherford) and SVcb 10. T.H. Mostert contributed the descriptions of SVcb 8 (with G.J. Bredenkamp and M.C. Rutherford), of SVcb 21 (with M.C. Rutherford and G.J. Bredenkamp). S.J. Siebert contributed the descriptions of SVcb 27 & 28 (both with F. Siebert, M.C. Lötter and M.C. Rutherford). G.J. Bredenkamp contributed the description of SVcb 11 (with M.C. Rutherford). P.J.D. Winter contributed the description of SVcb 24 (with M.C. Rutherford). C.R. Scott-Shaw contributed the description of SVs 5 (with L. Mucina and M.C. Rutherford). H. Bezuidenhout contributed the description of SVk 6. P.J. du Preez contributed the description of SVk 5 (with L. Mucina and M.C. Rutherford).

Assignment of growth forms of species listed was done by L. Mucina. Most references were sourced by M.C. Rutherford and L. Mucina.

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Albany Thicket Biome 10

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Figure 10.1 AT 8 Kowie Thicket: Kowie River meandering in the Waters Meeting Nature Reserve near Bathurst (Eastern Cape), surrounded by dense thickets dominated by succulent *Euphorbia* trees (on steep slopes and subkrantz positions) and by dry-forest habitats housing patches of FOz 6 Southern Coastal Forest lower down close to the river.

L. Mucina

1. Introduction: Delimitation and Global Perspective

Following the earlier work of Acocks (1953), the structurally unusual vegetation of the semi-arid river valleys of the eastern seaboard of South Africa was described as Valley Bushveld. This nomenclature probably followed the colloquial term used by the agriculturalists, mainly livestock farmers, who found it a largely impenetrable thicket which had to be 'opened-up' to allow access to domestic livestock (cattle and goats). According to Acocks, this comprised 'a semi-succulent thorny scrub 2–3 metres in height'.

Rutherford & Westfall (1986) classified the biomes of South Africa on the basis of dominant life-form combinations (Raunkiaer 1934, Cain 1950) and climatic features. Therefore, the areas now considered here to be the Albany Thicket Biome were classified by them as Savanna on the basis of the dominance of phanerophytes associated with, on average, hemicryptophyte co-dominance (Rutherford & Westfall 1986), although they acknowledged the existence of a variety of life-form combinations. This view continued in the work of Scholes (1997), who mapped the vegetation of the discussed region as a part of the broad-leaved Savanna. Following White & Moll (1978) and Cowling (1983), some evidence for its classification as a distinct structural and floristic unit was presented, and this provided justification for the later recognition of the Thicket Biome (Low & Rebelo 1996, 1998). Rutherford & Westfall (1986) noted that many parts of the areas classified here as Thicket Biome, namely Spekboomveld and the Fish River Scrub, Addo Bush and Sundays River Scrub forms of Valley Bushveld (Acocks 1988), had vegetation co-dominated by phanerophytes and chamaephytes. This corresponds to a 'missing biome' that they suggested may be recognised in the future. This concept is formally adopted here. Recent analyses, primarily within the STEP project (Cowling et al. 2003), have confirmed that the climatic uniqueness (Robertson & Palmer 2002) and peculiar vegetation structure resulting from a unique combination of constituent growth forms (Vlok & Euston-Brown 2002) as well as floristic diversity (including high regional endemism) justify its recognition as a biome.

The term 'Albany Thicket' is a concept recognised by the WWF (Olson et al. 2001, Burgess et al. 2004) where this vegetation type ('ecoregion') is listed as a part of the broader category (biome) 'mediterranean forests, woodlands, and scrubs', thus, as a part of the Cape Floristic Region—a misplacement that partly reflects the transitional nature of the biome. The same WWF categorisation does not recognise a global thicket biome. Various thicket formations in Africa, Madagascar, Asia, Australia and the Americas are spread over four different biomes. In Africa, patches of typical thicket are included in two other 'biomes': 'montane grasslands and shrublands' (e.g. Jos Plateau forest-grassland mosaic), and 'tropical and subtropical grasslands, savannas, and shrublands' (e.g. Somali *Acacia–Commiphora* bushlands and thickets). Worldwide, other thicket types are classified as 'tropical and subtropical dry broadleaf forests' (see Olson et al. 2001). In terms of vegetation structure and climate at least two other regions qualify as analogous to Albany Thicket. These include the thickets of the Chaco straddling the border areas between Argentina and Paraguay in South America (Lewis 1991, Cábido et al. 1992, 1994) and the Didiereaceae-rich semideciduous thickets (also called dry forests) of southern and southwestern Madagascar (Koechlin et al. 1974, Grubb 2003). Madagascar spiny thickets, largely equivalent in vegetation structure to southern Africa's Albany Thicket, are classified under 'deserts and xeric shrublands'.

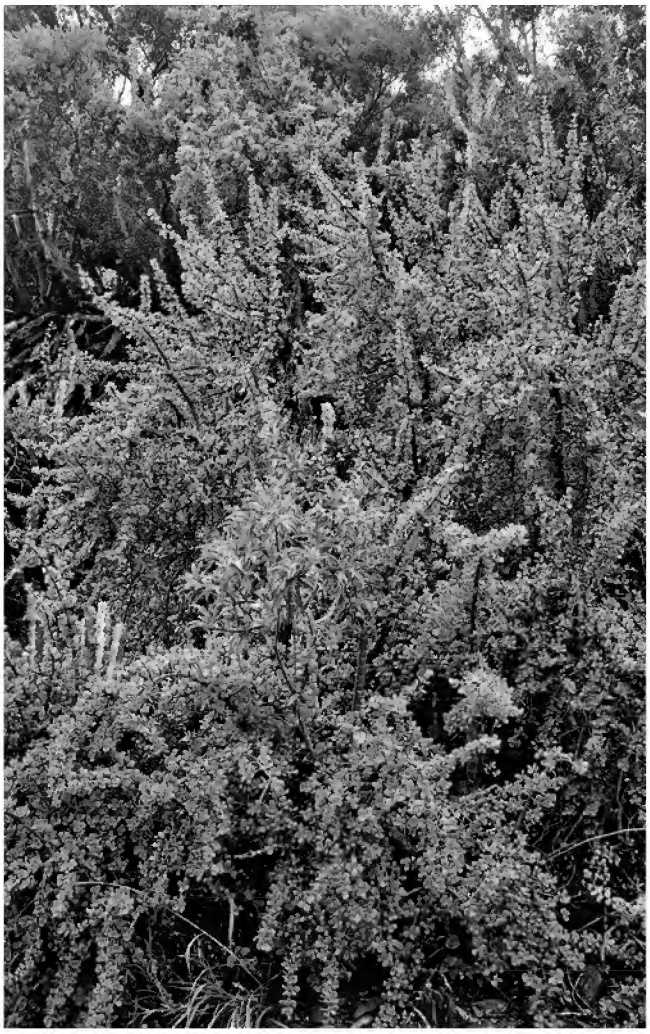
Table 10.1 Major correspondence between vegetation units and STEP vegetation types (Vlok & Euston-Brown 2002). Those STEP units are listed which have at least 80% of their area within the vegetation units and do not necessarily constitute a high proportion of the vegetation unit (these proportions are given under the headings in the description of each unit). Only Gouritz Valley Thicket is (much) less than 80%.

Vegetation Units	STEP
AT 1 Southern Cape Valley Thicket	Gouritz Valley Thicket
AT 2 Gamka Thicket	Gamka Arid Spekboomveld Gamka Spekboom Thicket Oudtshoorn Karroid Thicket
AT 3 Groot Thicket	Baviaans Spekboom Thicket Baviaans Valley Thicket Bethelsdorp Bontveld Groot Arid Spekboomveld Kleinpoort Karroid Thicket
AT 4 Gamtoos Thicket	Gamtoos Arid Spekboomveld Gamtoos Bontveld Gamtoos Thicket Gamtoos Valley Thicket Kromme Forest Thicket Otterford Forest Thicket Vanstadens Forest Thicket
AT 5 Sundays Noorsveld	Sundays Noorsveld
AT 6 Sundays Thicket	Elands Forest Thicket Koedoeskloof Karroid Thicket Kremlin Grassland Thicket Motherwell Karroid Thicket Sundays Spekboom Thicket Sundays Spekboomveld Sundays Thicket Sundays Valley Thicket Zuurberg Fynbos Thicket
AT 7 Coega Bontveld	Grass Ridge Bontveld
AT 8 Kowie Thicket	Albany Spekboom Thicket Albany Spekboomveld Albany Thicket Albany Valley Thicket Ecca Bontveld Salem Karroid Thicket Shamwari Grassland Thicket Thorndale Forest Thicket
AT 9 Albany Coastal Belt	Geluk Grassland Thicket Hamburg Dune Thicket Kiwane Dune Thicket Nanaga Savanna Thicket Paterson Savanna Thicket Zuney Strandveld
AT10 Great Fish Noorsveld	Fish Noorsveld
AT11 Great Fish Thicket	Crossroads Grassland Thicket Doubledrift Karroid Thicket Fish Spekboom Thicket Fish Thicket Fish Valley Thicket Hartebeest Karroid Thicket
AT12 Buffels Thicket	Buffels Thicket Buffels Valley Thicket Kei Thicket Mountcoke Grassland Thicket
AT13 Eastern Cape Escarpment Thicket	Escarpment Thicket
AT14 Camdebo Escarpment Thicket	Escarpment Spekboom Thicket

Perhaps also the Somali-Masai thickets as described by White (1983), the so-called 'Vine Thickets' of Australian Queensland (Webb 1978) and succulent-rich thickets of northern Venezuela and Colombia (Matteuci 1987) could be viewed as part of the global subtropical succulent-rich thickets.

Thicket in the valleys from the other side of the Great Kei River to the Thukela River in KwaZulu-Natal are not recognised here as being part of the Albany Thicket Biome (the Great Kei River Valley does contain some mapped Albany Thicket). In fact, this is a gradual transition from the characteristic bimodal rainfall, with no seasonal period of pronounced drought of the Albany Thicket to the summer-rainfall areas with dry winters typical of the Savanna Biome. Also in terms of species affinities, an increasing number of typical savanna species occur along this gradient towards the northeast. Woody elements of strandveld units to the west, including parts of the west coast, are not regarded as part of the biome despite their recognition as thicket by some authorities (e.g. Cowling 1984). The current delimitation of the Albany Thicket Biome closely follows (in most parts) the set of core ('solid') thickets of STEP (Vlok & Euston-Brown 2002) (Table 10 1). Much of the area of STEP's mosaic thickets is not here included in this biome, although small parts of some of them are incorporated where the evidence for belonging to an adjacent biome (Forest, Fynbos, Savanna, Grassland, Nama-Karoo and Succulent Karoo) appeared unwarranted. Valley Bushveld and Spekboomveld (Acocks 1953) of the Eastern Cape are similar in structure to thickets found in the equatorial and tropical regions of Africa, and Addo Bush (Acocks 1953) is similar to certain thickets of the Arid Lowveld (Acocks 1953, 1988) in the Mpumalanga Lowveld, northern KwaZulu-Natal and parts of Swaziland. The Albany Thicket also has a unique phylogenetic and biogeographic origin and is transitional between Nama-Karoo and the subtropical regions of the eastern seaboard of southern Africa.

Rainfall can occur at any time of the year in Albany Thicket, which occurs in a climatic interface between an all-year rainfall zone in the west and a stronger summer-rainfall zone in the northeast (Schulze 1997). Thicket vegetation is considerably fragmented and displaced by renosterveld and fynbos in the winter-rainfall zone and by grasslands and savanna in the summer-rainfall zone (Vlok & Euston-Brown 2002). The climate in itself is not the primary selective force for this pattern, but rather the fire regimes that are determined by seasonal precipitation. Evidence for this lies in the occurrence of outliers of thicket vegetation in fire refugia in the winter- and summer-rainfall zones. Although it is tempting to think that thicket is also differentiated by occurring mostly on deep soils rich in nutrients, it is not limited to or restricted by any particular soil type (Vlok & Euston-Brown 2002). The clumping of the vegetation is another distinguishing feature and appears to be strongly facilitated by below-ground animal activity (termite mounds, active mole rat colonies, aardvark burrows, earthworm activity). The clumps show elevated levels of C, Ca, K, organic and moisture content when compared with the adjacent soils (Palmer et al. 1988).



L. Mucina

Figure 10.2 Spekboomveld dominated by *Portulacaria afra* (Didiereaceae) in the Ecca Pass (north of Grahamstown, Eastern Cape).

L. Mucina

Figure 10.3 *Euphorbia triangularis* (Euphorbiaceae) at road from Addo to Zuurberg Inn (Eastern Cape)—a flagship species of the Albany Thicket Biome.

2. Major Vegetation Patterns

Thicket, according to a dictionary definition, is a tangle or dense growth of shrubs or trees. This is a physiognomic or structural description of a type of vegetation that may be found in many geographical areas. The term 'Thicket' (uppercase 'T') refers to the Biome, whereas 'thicket' (lowercase 't') refers to a structural type of vegetation. Within several biomes there may be a wide variety of structural vegetation types found which would, through high densities of woody plants, qualify as 'thicket' (see for instance chapters on Fynbos and Savanna in this book).

The vegetation of the Albany Thicket Biome is described in general as a dense, woody, semisucculent and thorny vegetation type of an average height of 2–3 m (Acocks 1953, Everard 1987), relatively impenetrable in an unaltered condition. During his journey of 1776–1777, Paterson found this vegetation impenetrable except along elephant tracks (Dyer 1937). It comprises a broad spectrum of physiognomic types reflecting gradients in climate, geology, soil and herbivory. The Albany Thicket Biome consists of various major vegetation types, and the wide variety of plant communities, with varying structure and species composition, has posed a challenge for researchers attempting to describe it. Acocks (1953, 1988) recognised four vegetation types currently classified as thicket, namely Valley Bushveld, Noorsveld, Spekboomveld and False Karroid Broken Veld. His thicket also contains small patches of other vegetation types that are embedded within thicket, e.g. Coastal Forest and Thornveld, Alexandria Forest, etc. Acocks also subdivided Valley Bushveld into valley thicket, scrub and Addo Bush. Typical valley thicket may be tall or low and may be composed of different proportions of succulent and nonsucculent plants. Following Acocks (1953), Martin & Noel (1960) described this vegetation as a Succulent Woodland Formation, with two subformations, the taller 'sub-succulent woodland' and the 'low succulent scrub'. In an effort to contextualise the vegetation relative to its origin, White & Moll (1978) included it in their Tongaland-Pondoland Regional Mosaic, as it was part of the vegetation with strong tropical affinity. This affinity was attributed to the presence of genera such as *Acacia, Brachylaena, Carissa, Euclea, Grewia, Pappea, Ptaeroxylon, Rhoicissus* and *Ziziphus*, which were able to extend down the coast due to the influence of the warm Agulhas Current. This led to incorporating the notion of the subtropical origin of the flora into nomenclature. Cowling (1983) recognised the floristic uniqueness of the regional vegetation and coined the term Subtropical Transitional Thicket, which had two formations, the mesic 'Kaffrarian Thicket' and the xeric 'Kaffrarian Succulent Thicket'. In further floristic research in the Subtropical Transitional Thicket, Everard (1987) described the Albany region as comprising two formations, the 'Xeric Succulent Thicket' formation which could be distinguished from the 'Mesic Succulent Thicket' because of its higher proportion of succulents (29% as opposed to 24% for the Mesic Succulent Thicket) and lower proportion of woody taxa (39% as opposed to 48%). The floristic data collected by these researchers were further supplemented by local-scale research in the Great Fish River Valley (Palmer 1981, Palmer et al. 1988) where gradients in species composition and structure were described. These were further elaborated upon by Evans et al. (1997), providing landscape-scale descriptions of the vegetation units. They described Tall Succulent Thicket (TST), Medium Succulent Thicket (MST) and Short Succulent Thicket (SST) of the Great Fish River Valley (Evans et al. 1997). MST is dominated by the leaf succulent *Portulacaria afra*, which comprises the most extensive version of the thicket, synonymous with subsucculent woodland of Martin & Noel (1960). SST, characterised by the dominance of *Euphorbia x bothae*, is represented by our Great Fish Noorsveld and is structurally similar to our Sundays Noorsveld, being shorter in height (1–2 m) and having a lower standing biomass than the MST. The TST is associated with cooler, moister southern aspects, comprises taller emergent *Euphorbia* species, and has a greater standing biomass than either the MST or the SST. Noorsveld (Acocks 1953) is a uniform, 1–2 m high scrub dominated by *Euphorbia coerulescens*, known as *noors*. Spekboomveld is dominated by *Portulacaria afra* (*spek*: Dutch word meaning bacon), thus referring to the apparent delicacy of the plant. Other vegetation found in the Albany Thicket Biome includes mosaics of thicket clumps and grassland, and various secondary vegetation types, including grassland and thornveld. Vlok & Euston-Brown (2002) also point to examples of a gradient of plant species turnover within the biome from the Buffels to the Gamtoos Rivers.

There is a wide range of growth forms and a high diversity of plant species, including leaf and stem succulents (Figure 10.2 and 10.3), deciduous and semideciduous woody shrubs and dwarf shrubs, geophytes, annuals, grasses, and a high diversity of plant species (Cowling 1983). The understorey typically hosts a relatively high diversity of dwarf succulent shrubs and forbs (mainly Crassulaceae and Aizoaceae), many of which are locally endemic and rare (Cowling 1983, Johnson et al. 1999, Vlok & Euston-Brown 2002, Vlok et al. 2003). Perennial grasses are often prevalent inside the clumps, with *Panicum maximum, P. deustum* and numerous *Eragrostis* species being found. The wide range of growth forms and taxa in Albany Thicket is a reflection of the transitional nature of thicket vegetation, being an interface between various types of forest, sclerophyllous shrublands, karoo and grasslands (Cowling 1984, Palmer 1990, Everard 1991, Kerley et al. 1995, Vlok & Euston-Brown 2002). A distinct guild of spinescent woody plants occurs in certain types of thicket, that develop recurved branches once the plants are more than 1 m tall and continue to produce the recurved branches even when mature (*deurmekaarbossie*; Vlok & Euston-Brown 2002). This unusual growth pattern results in an impenetrable barricade of thorny branches, because adjacent plants become entwined as they mature. Seeds of all woody species of this guild are contained within edible fruits and are bird-dispersed. The initial establishment of the woody species of this guild with their spinescent, recurved branches is followed by the growth of vines (often poisonous, wind-dispersed species) within the bush clumps. These often spinescent lianas further become interwoven within the individual bush clumps, to form the impenetrable vegetation so typical of, for example, Sundays Thicket. Once the matrix of shrub, grass and herb species is well established, herbivores play an important role in maintaining growth form richness.

There are insufficient data to describe major patterns of alpha, beta and gamma diversity in thicket vegetation fully, but a local study (Birch et al. 1999) gives some indication of alpha diversity in this vegetation. Within the MST, the alpha diversity in the clumps is higher (approx. 28 taxa per plot, range 15–44) than outside the clumps (using data from Birch et al. 1999), but the changes in diversity between clumps are low (total number of species in 58 plots was 195). Clump diversity in SST is 25 taxa per plot. TST contains 30 taxa per 100 m^2 plot.

3. Ecology: Climate, Geology, Soils and Natural Processes

3.1 Climate

Albany Thicket is found in semi-arid areas of the Eastern and Western Cape, with 200–950 mm MAP (Vlok & Euston-Brown

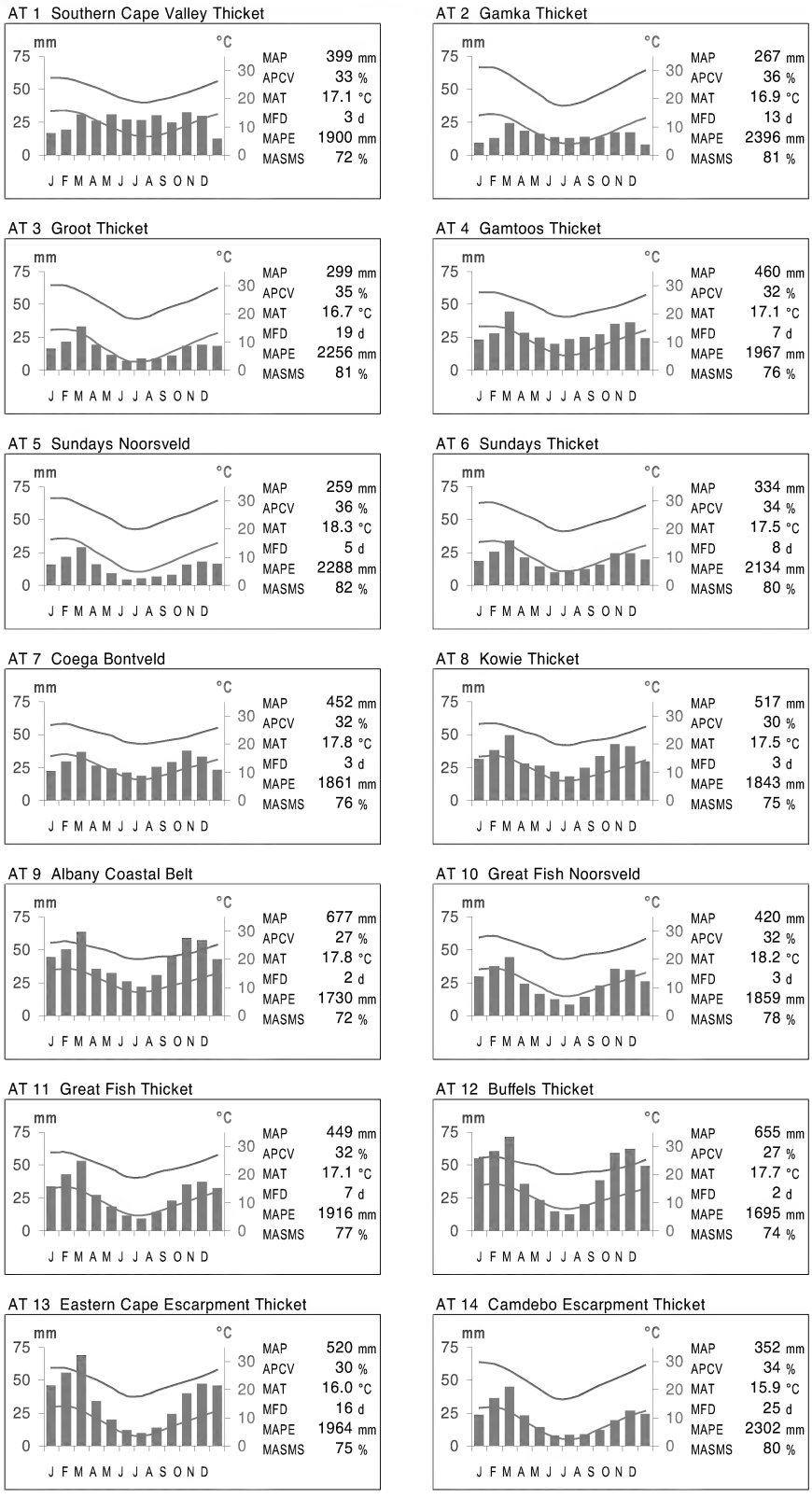


Figure 10.4 Climate diagrams of Albany Thicket Biome units. Blue bars show the median monthly precipitation. The upper and lower red lines show the mean daily maximum and minimum temperature respectively. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days (days when screen temperature was below 0°C); MAPE: Mean Annual Potential Evaporation; MASMS: Mean Annual Soil Moisture Stress (% of days when evaporative demand was more than double the soil moisture supply).

2002; see also Figure 10.4). Two prevailing climate systems (all-year rainfall to the southwest and summer rainfall to the northeast) converge in the region, resulting in all-year rainfall, with spring and autumn maxima (Aucamp & Tainton 1984). All the Thicket vegetation units have nonseasonal rainfall, with optima in March and October or November. The increase in summer rainfall to the northeast corresponds with a change in vegetation towards grassland and thorn-tree savanna; the increase in winter rainfall to the southwest corresponds to a gradual replacement by fynbos. In these two zones interannual variations in climate, in combination with different fire regimes and substrate factors, may lead to temporal species turnover and changes in dominance between thicket species and those from adjoining biomes.

Rainfall is unreliable, with an average coefficient of variation of 25–36% (as low as 18% at the coast and along the escarpment, and as high as 40% in Gamka Thicket), and droughts of several months are common. There is a 25% chance of not receiving 80% of the mean rainfall in any given year (Aucamp & Tainton 1984). In addition to this unpredictable rainfall regime, the inland region experiences high temperatures in summer (exceeding 40°C on occasion) and low temperatures with frost (0 to 64 days) in winter. The dominant plants in these inland regions reflect this harsh climate, with a high degree of succulence and sclerophylly. The larger shrubs and trees are deep-rooted, and plants with storage organs are common. Studies on primary productivity in thicket have shown that the life strategy in most species appears to be one of slow growth (Aucamp & Tainton 1984).

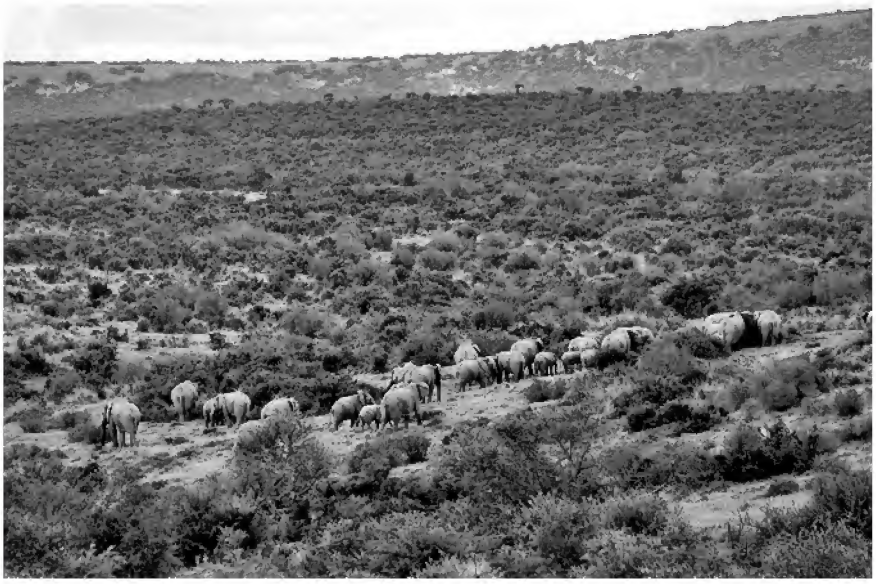
Thicket vegetation growing close to the coast experiences less extreme climatic variability due to the influence of the ocean. Coefficients of variation here are usually lower than 30% and the number of days of frost fewer than 10 per year. There also tends to be a higher annual rainfall, with the vegetation less succulent, and there is a lower degree of leaf sclerophylly and more predictable growth rates.

Vlok & Euston-Brown (2002) suggested that fog may be important even in arid thickets, with a high incidence of bark and ground lichens.

3.2 *Geology and Soils*

The dominant geological feature in the region occupied by the Albany Thicket Biome is the east-west trending Cape Fold Belt. These mountain ranges consist mostly of the folded strata of the Cape Supergroup, of which the sandstone and quartzite of the Table Mountain and Witteberg Groups (Ordovician to Silurian and Devonian, respectively) are biogeographically important (Gibbs

Russell & Robinson 1981) in that they typically support outlier populations of fynbos and renosterveld within a matrix of thicket. Early Karoo Supergroup sedimentary rocks, namely the Dwyka and Ecca Groups, are also folded in the northern margin of the Belt, where they overly the Cape Supergroup rocks. The main folding event took place around 250 mya. Another significant topographical feature is the escarpment which consists mostly of the fine-grained sediments of the Beaufort Group of the Karoo Supergroup. These rocks of Permian and Triassic age are also intruded by Jurassic Karoo Dolerite dykes and sills that formed in association with the break-up of the supercontinent Gondwana. This rifting of South America from Africa also resulted in the formation of half-graben structures within the Cape Fold Belt that formed the Cretaceous depositional basins for the Uitenhage Group sediments. This sequence includes Enon conglomerates as well as other finer-grained clastic sediments. During the Tertiary Period, times of relatively high sea level caused the peneplanation of large areas between the coast and the mountains. As the sea level dropped, the accelerated erosion resulted in the dissection of the plains by a series of large river valleys such as the Fish, Sundays and Gamtoos. It is these large valleys that gave rise to the name 'Valley Bushveld', as thicket vegetation is restricted to their slopes and floors. Recent deposits of shallow marine sandstones and coastal dunes are present along the coast in many parts as a result of more recent fluctuations in sea level.



L. Mucina

Figure 10.5 AT 6 Sundays Thicket: Spekboomveld (*Portulacaria afra*) with a herd of last Cape elephants (*Loxodonta africana*) browsing in the Greater Addo Elephant National Park (Eastern Cape).

The soils derived from these rocks vary considerably over a variety of scales, closely tracking the underlying geology and topography. The fine-textured rocks of the Karoo Supergroup typically give rise to deep, well-structured soils. A repeated catena pattern of shallow rocky soils on upper slopes and deep fine-textured soils in the valley floors is evident in the series of river valleys through the Eastern Cape. The more coarse-textured rocks of the Witteberg and Table Mountain Groups are typically found in sharply folded mountain systems, and the combination of steep slopes and the high percentage of quartz sand gives rise to coarse, unstructured soils that are shallow and nutrient-poor. Much of the fine-scale pattern in the vegetation is likely to be attributable to the interaction of climate and pedology (e.g. Palmer et al. 1988).

3.3 Natural Processes

Albany Thicket shows little annual fluctuation in its relatively high perennial cover or biomass, irrespective of the relatively high coefficient of variation in mean annual precipitation or with droughts that may last months or even years (Aucamp & Tainton 1984). This general resistance to drought probably involves several mechanisms such as below-ground storage organs, sclerophylly, CAM photosynthesis and succulence. Unlike other semi-arid ecosystems such as savannas and certain Mediterranean-type shrublands, intact Albany Thicket does not support a regular or widespread fire regime (Kerley et al. 1999a). The combination of the low availability of fuel and the high degree of succulence has largely excluded fire from Albany Thicket (Kerley et al. 1995). However, the occurrence of fire may be increasing in degraded areas due to the replacement of the nonflammable succulent component with a potentially flammable field layer (Vlok & Euston-Brown 2002).

Albany Thicket has historically supported a high diversity and density of indigenous herbivores, ranging in size from duiker to elephants (Skead 1989). Early accounts of the travellers and explorers in the region report high numbers of elephant (see references in Stuart-Hill 1992). The high nutrient status of the vegetation and proximity of many perennial rivers suggest that these large herbivores were permanent residents (Stuart-Hill 1992) and support the hypothesis that herbivory has played an important role in shaping vegetation and ecosystem properties (Kerley et al. 1999b). The impact of indigenous herbivory has been reflected in the evolution of the plant species, many of which are well defended against browsing (Everard 1987, Haschick 2002). Midgley (1991) and Stuart-Hill (1992) describe the potential impacts of large herbivores through herbivory, trampling and dunging, and suggest that large mammals were the primary patch disturbance agents in Albany Thicket prior to their extirpation in the 1800s.

Megaherbivores, such as elephants and rhinos, seem to be important in maintaining the structure of thicket vegetation (Stuart-Hill 1992), although they do impact on the diversity of the dwarf succulents (Johnson 1998, Johnson et al. 1999, Cowling & Kerley 2002). Stuart-Hill (1992) demonstrated the role that elephants play in maintaining vegetation structure and promoting asexual recruitment of *Portulacaria afra* in Albany Thicket (Figure 10.5). Elephants encourage coppicing in woody shrubs and promote the development of a skirt around *P. afra* plants. Sigwela (1999) and Sigwela et al. (2004) showed how significantly more seeds are dispersed by indigenous herbivores than by goats. There have been several previous studies that examine the impact of goats and indigenous megaherbivores on biodiversity and ecological processes. Most of the earlier work was done from an agricultural production perspective, where the vegetation was viewed primarily as a resource for browsing animals (Aucamp & Tainton 1984). There are two key vegetative traits that contribute to degradation of the Albany Thicket. Firstly, despite a high standing biomass, Albany Thicket has a low annual production, thus giving a false impression of the amount of forage available for animal production (Aucamp & Tainton 1984). Another is the very slow recovery periods of

the main forage species such as *P. afra*, which can take up to 18 months to recover from 50% defoliation by goats (Aucamp & Tainton 1984). Also, the feeding behaviour of goats, both as individuals and as herds, differs from that of indigenous herbivores (Danckwerts 1984, Stuart-Hill 1992). Goats are gregarious animals and tend to feed in groups around individual plants and vegetation patches, leading to very high localised impacts. They also damage the structure of bush clumps by browsing from the sides and exposing the interior to the forces of desiccating winds and erosion by water (Stuart-Hill 1992).

4. Origins and Biogeography

4.1 Origins of the Albany Thicket Biome

The Albany Thicket Biome is part of a poorly defined global Subtropical Thicket Biome, characterised by subtropical, semixeric conditions. Such conditions became globally important during the Eocene characterised by climate both colder and drier than the usual (Zachos et al. 2001). Hence one can expect that it was this period when most thicket plant lineages originated. In support of this hypothesis, Cowling et al. (2005) have shown that many plant groups characteristic of thicket vegetation (as well as associated insect taxa) are of Eocene age, although both older and more recent taxa currently represent important thicket components. This timing is confirmed by both palynological evidence (Boureau et al 1983, Salard-Cheboldaeff & Dejax 1991) and recent calibration attempts (Davies et al. 2004).

Ebenaceae, two clades of Celastraceae, Sapindaceae, Didiereaceae (currently including also *Portulacaria*) and Cotyledonoideae (Crassulaceae) can be reasonably listed as those families well represented in the Albany Thicket Biome which diversified most likely in the Eocene (Cowling et al. 2005). Generally, these are taxa endemic to, or most diverse in, semixeric African vegetation. Many other clades will probably be added to this list as more well-dated phylogenies become available.

Another set of taxa are likely to represent true Gondwanan relicts, and therefore are of Mesozoic age, although they may have adopted a semixerophytic habit only during the Eocene or later. These are the cycads of the genus *Encephalartos* as well as *Cussonia* (Araliaceae) and *Strelitzia* (Strelitziaceae; Figure 10.6), all having their closest relatives in South America, Madagascar and Australia.

Some of the succulents and geophytes are of more recent origin (Klak et al. 2004, Procheş et al. 2006), presumably dating back to the more pronounced mid- to late Tertiary aridification. These are groups that are generally centred in the arid southwest of southern Africa (Nama-Karoo and Succulent Karoo Biomes), but have clades typical of the Albany Thicket Biome, indicating a retrocolonisation of a semixeric environment from fully xeric conditions. Examples are several clades within Aizoaceae and within Asteraceae, specially the tribe Senecioneae (Cowling et al. 2005).

The geographic origins of Albany Thicket are poorly understood, and southern African fossil sites of relevant age are few. The fossil woods from Bogenfels (Namibia) indicate an assemblage more similar to present savanna or arid bushveld than to the Albany Thicket (Bamford 2000). Older sites, such as the pollen flora of Banke in Namaqualand (Cretaceous/Early Tertiary, Scholtz 1985) show no clear evidence of thicket elements. The Umzamba site in the Eastern Cape (of similar age) contains a variety of fossil woods, some belonging to the Euphorbiaceae, more likely typical of forest sites (Bamford 2000). The assemblages that can be quite clearly associated with the present-day Albany Thicket taxa come from other parts of the African continent, mainly from East Africa, such as the variety of woody plants of Ebenaceae, Celastraceae and Oleaceae occurring in Eocene to Miocene deposits from Ethiopia, Uganda and Egypt (Laudoueneix-Dupéron & Dupéron 1995). Recently, Schrire et al. (2005) have suggested that those plant forms characteristic of a global 'succulent biome' (covering also the parts of global Subtropical Thicket Biome) first appeared during the Eocene in the region of the Tethyan Ocean (the Mediterranean Sea being a remnant of the latter), in conjunction with the aridification that affected this region more drastically than others. This area is likely to have represented the cradle of the Fabaceae. An early branch that supports this hypothesis is the tribe Detarieae, which includes the southern African endemics *Schotia* and *Umtiza*. A northern origin is also supported by the Tertiary records of typical thicket genera such as *Ehretia* and *Rhoicissus* from Europe, where they are now extinct (Gottschling et al. 2002, Ingrouille et al. 2002). The above evidence may suggest that the Albany Thicket Biome may represent a relict formation with deep roots in the Eocene.

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Figure 10.6 *Strelitzia reginae* (Strelitziaceae)—a flagship beauty among South African plants (near Ecca Pass north of Grahamstown, Eastern Cape).

Currently, several centres of semixeric and xeric plant diversity can be distinguished on the African continent (including Madagascar), the most important being the Succulent Karoo Region, the thicket vegetation of the Eastern Cape, the KwaZulu-Natal/Limpopo high diversity zone, several smaller centres in East Africa, the Horn of Africa (including the Island of Socotra), the Mediterranean Basin, and southern and southwestern Madagascar. Three of these areas appear to have been most important in harbouring the earliest branches in various semixeric lineages, namely the Succulent Karoo Region, the Eastern Cape and

western Madagascar. Various groups appear to have colonised large parts of the continent having originated in one of these three areas. The southern African-Madagascan semixeric connection is particularly interesting, given that Madagascar has been separate from the African mainland since the Cretaceous. Nevertheless, the distance was never large enough to prevent multiple crossing events by wind-dispersed as well as bird-dispersed plants (Grubb 2003, Pell 2004). At the same time, temporary aridification events during the Tertiary (and recent ones associated with Pleistocene glaciations) may have facilitated exchange events between southern Africa and the Horn of Africa and consequently the entire Mediterranean region along an arid corridor, even in groups with limited dispersal abilities (see Axelrod & Raven 1978).

The floristic uniqueness of the Albany Thicket Biome, marked by a significant contingent of local endemics, suggests an uninterrupted existence in its current geographic distribution area. However, variations in size may have been great. The absence of endemic vertebrates—as would be expected given the relatively large area covered by the biome—strongly suggests that thicket vegetation suffered several constrictions in recent times, most likely associated with Pleistocene glacial cycles (see Cowling et al. 1999). Then the Albany patch may not have been much larger than other vegetation patches of similar composition growing under different climatic conditions in fire-free pockets along the eastern escarpment of southern Africa and the Great Rift Valley. The establishment of a relatively large nonseasonal rainfall and fire-protected area in the Eastern Cape may have allowed it to expand to its current extent.

Browser pressure and the unreliable arid climate of the region have probably been the driving forces in the evolution of Albany Thicket since the Last Glacial Maximum (LGM), 18 000 to 21 000 years BP (Palmer 1990). Yet, in the face of the impressive array of indigenous herbivores (not even considering arthropods), Albany Thicket appears to show little fluctuation (in recent decades) in standing biomass over short periods of time (Aucamp & Tainton 1984). This feature sets it apart from most of the other herbivore-driven systems, such as savannas (Scholes & Walker 1993) and grasslands (O'Connor & Bredenkamp 1997), where the herbivores (Owen-Smith & Danckwerts 1997), fire, and climate (Schulze 1997) are primary determinants of plant biomass. In Albany Thicket, indigenous herbivores do reduce plant biomass, but the overall patch structure is retained (Cowling & Kerley 2002). In spite of the widespread and varied defences employed by plants, and their apparent resistance to herbivory, the onset of domestic herbivory was the catalyst to degradation of the Albany Thicket ecosystems.

4.2 Biogeography

The Eastern Cape flora corresponds with the convergence of five of White's (1983) phytochoria (Cowling 1983, Cowling & Campbell 1983), namely the Cape Region, the Karoo-Namib Region (later subdivided; see chapter on Succulent Karoo in this book), the Maputaland-Pondoland Regional Mosaic, the Afromontane Region and the Kalahari-Highveld Regional Transition Zone. As a result, the flora has been described as complex and transitional and the convergence of these phytochoria in the Eastern Cape has led to a huge 'tension' zone (Cowling 1983). No less than 21 of 70 national Acocks (1953) Veld Types are represented in the Albany area, which constitutes the core of the Albany Thicket Biome. Subtropical Maputaland-Pondoland forests enter Albany Thicket from the northeast along the coast, penetrating up the river valleys after the establishment of warmer wetter conditions that followed the LGM (Palmer 1990). The succulent and dwarf shrublands of the Karoo-Namib phytochorion penetrated down the river valleys from the arid interior and graded into the forest and thicket. Afromontane (afrotemperate) forest elements are found from the sea level forests to the forest pockets in the interior mountains, possible refugia from the LGM. Cape fynbos elements are well represented on the infertile soils derived from the Cape Supergroup rocks (Cowling 1983). The relative distributions of these phytochoria are held in balance by environmental drivers such as climate and, more recently, land use. The result is a mosaic of plant communities with different or mixed chorological affinities (Cowling 1983).

The Albany Thicket is the Eastern Cape biome supporting the highest number of endemic taxa. It forms the core of the so-called Albany Centre of Endemism (Van Wyk & Smith 2001). Some authors (e.g. Gibbs Russell & Robinson 1981) consider the Albany region to have relatively low levels of endemism in comparison to the rich centres of endemism elsewhere in southern Africa. Many of the species in the Albany Thicket Biome are considered to have their centres of distribution elsewhere, and it has been suggested that the region does not have a strongly characterised flora (Gibbs Russell & Robinson 1981, Hoffman & Cowling 1991). However, endemism in this region is probably grossly under-estimated (Van Wyk & Smith 2001) and the region represents a centre of endemism for karroid succulents (Hoffman & Cowling 1991, Van Wyk & Smith 2001), most of which are restricted to the thicket vegetation in the region. High percentages of endemism are reported for the families Asclepiadaceae, Crassulaceae, Euphorbiaceae and for several families of the Asparagales (see Smith & Marx 1990). High numbers of local endemics are known to occur and Cowling & Hilton-Taylor (1994) report 51 Red Data taxa, 200 endemics and 2 000 taxa in the Albany hotspot, an area that corresponds broadly with the Albany Centre of Endemism (Van Wyk & Smith 2001). An analysis of threatened species in the Albany Centre of Endemism (Victor & Dold 2003), which includes the Albany Thicket, indicates that 180 (61%) of the species evaluated have a very narrow distribution range. This list does not include all endemic taxa, but is similar to the 200 endemics reported by Cowling & Hilton-Taylor (1994) and 205 by Lubke et al. (1986) that give an overall estimate of 10% endemism for the Albany Centre of Endemism. There are many more near-endemics (with about 90 listed in the descriptions of the vegetation types of the biome). Van Wyk & Smith (2001) report 365 endemic/near-endemic succulents in the Albany Centre of Endemism; inclusion of nonsucculents would expand this list considerably and indicates that 10% endemism is probably an under-estimate. Vlok & Euston-Brown (2002) provide a list of 322 out of 1 588 species (20%) in subtropical thicket that are endemic. The endemics of the region are a mixture of palaeoendemics and neoendemics, with few endemic genera and no endemic families (Van Wyk & Smith 2001).

5. Land Use History

Prior to the arrival of colonial settlers in the early 1800s the region was sparsely populated by humans. Most human activity was concentrated along the Sundays River Valley, the principal source of perennial water in the area. Early travellers described the area as an unbroken expanse of dense thicket north of Uitenhage (Skead 1989). Initially, domestic stock was restricted by the high densities of ticks (carrying the fatal heartwater disease) and difficultly of access for the stock associated with the very dense bush, and the limited perennial water (A. Rudman, personal communication). Later, the use of dips and boreholes allowed farmers to increase their stock densities and enter into

new areas of thicket. This trend resulted in the opening up of large areas of thicket. More recently, an increasing number of farmers are switching from stock to game farming (Smith & Wilson 2002) as reduced availability of forage and increased variability in forage production make stock farming less profitable and sustainable.

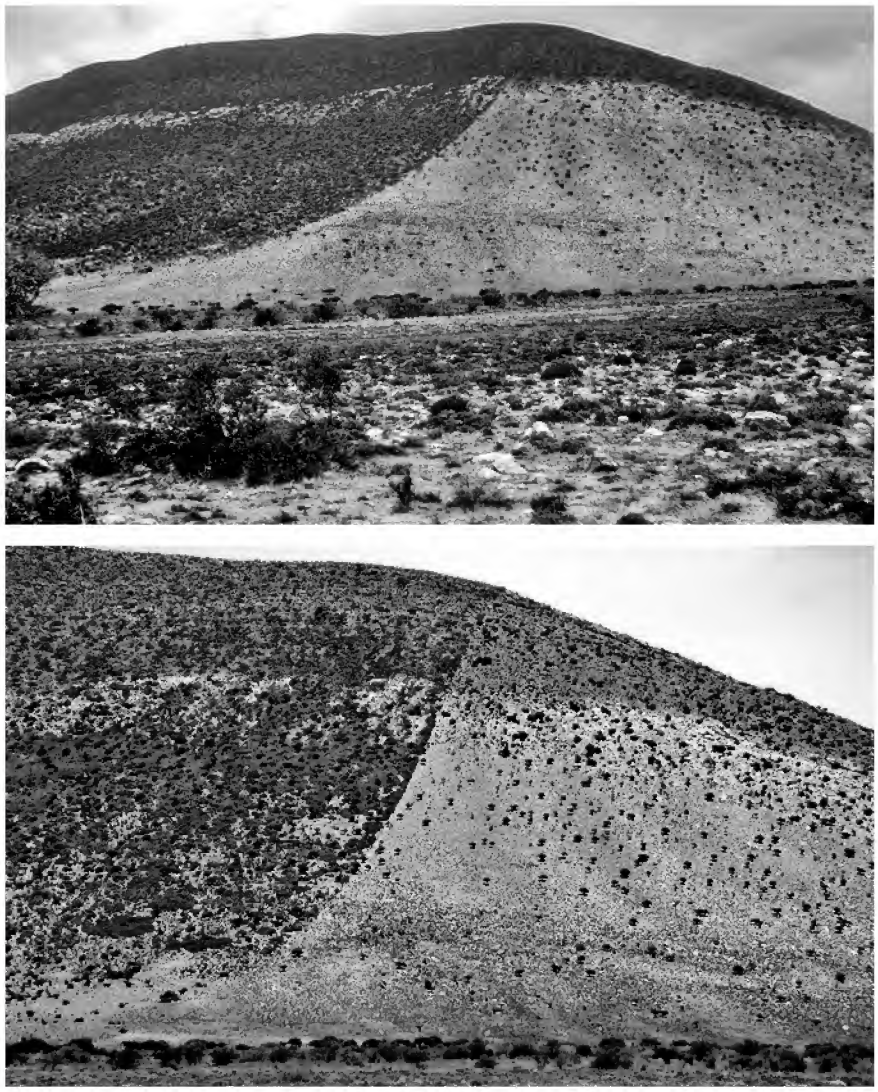
With the arrival of the first European settlers in the early 1800s, began the extirpation of megaherbivores (elephant and black rhino) and significant reductions in the populations of small (e.g. duiker) and medium-sized (e.g. bushbuck and kudu) herbivores (Kerley et al. 1999b). Since then, the high-quality forage available in intact Albany Thicket has been used to support extensive pastoralism. Goats were the most successful domestic species in the region since they were able to make use of the high biomass of browse. Despite its long history of herbivory, Albany Thicket has not displayed resilience to domestic herbivory and there is much evidence to show that commercial pastoralism has led to ecosystem-level degradation (Aucamp & Tainton 1984, Hoffman & Cowling 1990, Moolman & Cowling 1994, Kerley et al. 1999a, b). Approximately 92% (7 500 km^2) of Albany Thicket in the Eastern Cape has been degraded to some degree over the past 200 years (Lloyd et al. 2002). Much of this degradation occurred decades ago when there was little understanding of sustainable stocking levels in Albany Thicket. Anecdotal accounts suggest that government-recommended stocking rates during the 1950s were at least 20-fold those of today. Furthermore, it seems that some thicket farmers deliberately over-stocked goats to open up the dense bush, as much of the biomass was inaccessible to other stock, and high levels of tick-borne heartwater disease were associated with dense bush (A. Rudman, personal communication). Thus, the area is now dominated by grasses and ephemeral forbs, with remnant trees and pockets of thicket (Figure 10.7).

Considering that thicket has historically been exposed to a range of indigenous herbivores, from duiker to elephants, sometimes in very dense populations (Skead 1989), it is interesting to note why it collapses so rapidly in the face of domestic herbivory. The production potential of Albany Thicket is easily destroyed by domestic herbivory due to a combination of the feeding behaviour of goats (Stuart-Hill & Danckwerts 1988) and the slow growth rate of the plants (Aucamp & Tainton 1984). Stuart-Hill (1992) shows how goats feed into the sides of bush clumps, exposing the interior and reducing essential vegetative recruitment. In comparison, indigenous herbivores that browse from the top of the bush clumps, encourage vegetative recruitment. If damaged by over-utilisation, the woody component of the vegetation does not recover within management time frames (Stuart-Hill 1992). In comparison to other woody and herbaceous systems, such as savannas, removal of the woody component does not necessarily lead to a more productive grass understorey. The herbaceous layer is not a reliable source of forage, as its production closely tracks rainfall patterns (Stuart-Hill 1992).

6. Current Status, Threats and Actions

The current Albany Thicket vegetation is highly transformed and shows high levels of degradation (Lloyd et al. 2002, Palmer et al. 2004). Of the untransformed Thicket, only 11% is still in pristine condition and 60% is severely degraded (Lloyd et al. 2002). Approximately 7.3% has been transformed. The factors responsible for degradation and obliteration across the biome include cultivation in the moister regions, herbivory by livestock in the drier regions and urban settlement along the coast (Lloyd et al. 2002). The pressure on individual species, likewise, is high. Of the 126 species threatened with extinction in the Albany Centre of Endemism, the major threats, in decreasing order of importance, are illegal collecting, urban residential development, industrial development, alien plants, agriculture (including browsing/grazing), medicinal harvesting and forestry (Victor & Dold 2003).

Current land use pressure on thicket vegetation includes primarily urbanisation, agriculture and afforestation/alien trees



J.P.H. Acocks

L. Mucina

Figure 10.7 AT 3 Groot Thicket: Fence-line effect in the Spekboomveld near Willowmore (Eastern Cape), 13 km south of Beervlei Dam. To the right of fence small trees and shrubs of *Euclea undulata, Pappea capensis, Rhigozum obovatum* and *Lycium oxycarpum* are left. Photographed by J.P.H. Acocks in the 1950s (above top) and in 1998 (above). See also Acocks (1979, Figure 8).

(Cowling et al. 2003). Two urban areas constitute a significant pressure on surrounding vegetation, namely the Nelson Mandela Metropole (including Port Elizabeth) and environs and the corridor spanning Buffalo City (East London) and the Amathole range (Cowling et al. 2003). The Nelson Mandela Metropole is considered to constitute a significant urbanisation pressure on the surrounding landscape and therefore on biodiversity (Cowling et al. 2003). Coega is a specific nucleus of urban sprawl due to the development of the Industrial Development Zone that will result in the attraction of large populations of people to the surrounding areas. The Albany Thicket vegetation types from this node most at threat are Coega Bontveld and, to a lesser extent, Sundays Thicket. Further northeastwards, Buffalo City and its extensions towards Bisho constitute a threat to Buffels Thicket, but this vegetation is more widespread in areas removed from this threat.

A recent report detailing the effects of climate change on vegetation in South Africa (Rutherford et al. 1999, WWF 2001) did not treat the Albany Thicket as a separate biome. However, according to modelled climatic scenarios over the next 50 to 100 years, the area occupied by Thicket vegetation would undergo a major shift in climate, becoming warmer with fewer days when soil moisture and temperature are suitable for plant growth. Only the extreme western and eastern portions of the biome would be less affected. Fynbos would extend slightly eastwards, suggesting that bimodal climate conditions will also move eastwards shifting Albany Thicket in that direction. On the basis of this type of analysis, it is possible that there might be a significant loss in area of the Albany Thicket types that do not occur in the kind of habitat available in these eastern regions, for example steep-sided river valleys. Predictions are that approximately 20% of the area where *Portulacaria afra* is found, would become unsuitable for this species under modelled scenarios of climate change (Robertson & Palmer 2002). The worst-affected areas are likely to be the coastal region around Algoa Bay, almost at the core of the biome, as well as the Keiskamma River Valley and areas to the south of Graaff-Reinet (Robertson & Palmer 2002). Climate change effects are, however, more complex, and it is likely that changes in the variability of climate parameters will have as big an influence on the survival and distribution of species as changes in the mean values of parameters (O'Connor & Roux 1995).

A number of megaconservancy networks (MCNs) and expanded parks have been proposed or are in the process of being established within the biome, including the Fish-Kowie MCN, the Gqunube-Amathole MCN, the Kei MCN, the Gouritz-Little Karoo MCN, the Baviaanskloof MCN and the Addo-Camdebo MCN, many of which include existing reserves. Despite the formation of these new conservation areas, conservation of the variety of Thicket vegetation will not be achieved without the establishment of new protected areas that conserve unprotected types of Albany Thicket. One of the major conservation initiatives in the biome area is the expansion of the Addo Elephant National Park, which began in 1997 and is still under way, made possible by funds from the government (DEAT) and foreign donors (primarily the Global Environmental Fund). The park is currently 148 000 hectares in extent (December 2004) and will eventually cover 240 000 hectares to become South Africa's fourth largest National Park.

Large areas of Albany Thicket degraded by overgrazing and invasive alien plants require a substantial restoration effort for the achievement of both pattern and process conservation targets (Cowling et al. 2003). The Working for Water Programme may restore the function and biodiversity of the catchment through the systematic eradication of alien invasive plants. However, rehabilitation efforts to restore Albany Thicket vegetation are likely to be very labour-intensive and require long-term investment of resources (Todkill 2001). Much of the degraded thicket was *Portulacaria afra*-dominated and the re-establishment of this species is necessary to begin to restore the vegetation. However, this is costly and unlikely to be undertaken by private land owners. Due to the high carbon-storage ability of *Portulacaria afra*-dominated thicket (Lechmere-Oertel 2003), the opportunity exists to initiate restoration through the international carbon credit system (Cowling et al. 2003).

7. Further Research

The main focus of the research in the Albany Thicket Biome appears to have been on the agricultural potential of these areas and the contribution that Thicket may make towards animal production, both domestic (e.g. Aucamp 1976, 1979, Aucamp & Tainton 1984, Danckwerts 1984) and wild (e.g. Cowling & Kerley 2002), as well as on the influence of grazing and browsing on thicket structure and function (e.g. Lechmere-Oertel 2003). Two 'Valley Bushveld Symposia' (proceedings published in 1991 and 1996) generated much interest and data on the economic and conservation aspects of the Albany Thicket Biome.

Earlier studies (Dyer 1937, Story 1952, Acocks 1953, 1988, Archibald 1955, Lubke et al. 1986) were broad in nature, but provided a good first approximation of vegetation patterns. Some detailed studies have been undertaken, e.g. Cowling (1984), Everard (1987), Palmer (1988), Birch et al. (1999), Judd (2001), but most of these are concentrated in specific areas and have been undertaken at different levels of intensity. There is an urgent need for detailed floristic studies on the different vegetation units within the Albany Thicket Biome to provide baseline information on diversity, structure and species composition, as well as on the distribution of individual species and the relationship between the different parts of the Biome. Two major universities located in the region (the Nelson Mandela Metropolitan University in Port Elizabeth and the Rhodes University in Grahamstown) are the institutions that should take the lead to deal with these challenges.

Recently, the Subtropical Thicket Ecosystem Planning Project (STEP) was an important measure in identifying ecologically uniform areas on the basis of remote-sensed data and environmental parameters. The STEP (Cowling et al. 2003, Pierce et al. 2005) identified a number of research priorities of an ecological nature, including the need to identify dynamics within different Thicket types, how these dynamics compare in intact and degraded forms of Thicket, what the biological indicators of ecosystem health are in different Thicket types, what they mean and how they can be used in monitoring programmes, to what extent different Thicket types are dependent on herbivory by different guilds of indigenous herbivores for the maintenance of biodiversity and ecosystem health, and what processes are essential across all spatial and temporal scales for the long-term maintenance of Thicket biodiversity.

8. Descriptions of Vegetation Units

AT 1 Southern Cape Valley Thicket

Aloe Scrub (Muir 1929). VT 23 Valley Bushveld (44%), VT 46 Coastal Renosterbosveld (39%) (Acocks 1953). LR 63 South and South-west Coast Renosterveld (86%) (Low & Rebelo 1996, 1998). BHU 93 Gouritz Mesic Succulent Thicket (74%) (Cowling & Heijnis 2001). STEP Gouritz Valley Thicket (63%) (Vlok & Euston-Brown 2002).

Distribution Western Cape Province: The core of the distribution is in river valleys of the Goekoe River (between Riversdale and Still Bay) with the largest patch in the Gouritz River Valley (between Herbertsdale and the Gouritzmond) and is found in unmapped smaller patches of the Groot Brak and Klein Brak Rivers as well as the Kaaimans River (here at its easternmost limit). Towards the west this vegetation is found (unmapped) in valleys of the Duiwenhoek and Slang Rivers and reaches its westernmost limits of distribution in the Breede River Valley. Altitude 20–200 m.

Vegetation & Landscape Features Steep slopes of deeply incised valleys of rivers flowing mainly in a north-south direction and dissecting the Southern Cape coastal peneplain. Medium-sized to tall (3–5 m), dense thicket composed of sclerophyllous (often spinescent) evergreen shrubs (e.g. *Euclea, Grewia, Gymnosporia, Putterlickia, Rhus, Sideroxylon, Tarchonanthus*) as well as an important admixture of a microphyllous (partly ericoid) shrub element (*Athanasia*, *Elytropappus, Oedera, Stoebe*) and with a prominent (locally also dominant) succulent, rosulate tree, *Aloe ferox*. The low shrub layer contains a high proportion of succulent shrubs (*Aloe, Crassula, Euphorbia, Ruschia*). Grasses are abundant in some favoured grazing areas.

Geology & Soils Shallow, loamy-clayey soils (mostly Glenrosa and Mispah) derived from siltstone and shales of the Bokkeveld Group in the western part of the area, and Jurassic Enon conglomerates and other clastic sediments of the Uitenhage Group in the eastern part of the area. Where on hard Ordovician Table Mountain sandstone, only on the Aasvogelberg range—on rocky south-facing slopes with organic-rich soils (Rebelo et al. 1991). Fc land type predominates, while Ia is of lesser importance.

Climate Nonseasonal rainfall with several slight optima (in March, May, August, October), and with driest summer months December to February. MAP 400 mm, which ranges from about 340 mm in the west (Swellendam) to about 940 mm in the east (Wilderness). Frost is infrequent. MAT falls within warm-temperate range (17°C). Mean monthly maximum and minimum temperatures for the nearby Riversdale weather station are 37.5°C and 0.2°C for February and July, respectively and corresponding values on the coast for Mossel Bay (Cape St Blaize) are 29.6°C and 7.4°C for April and August, respectively. Also see climate diagram for AT 1 Southern Cape Valley Thicket (Figure 10.4).

Important Taxa Succulent Tree: *Aloe ferox* (d). Small Trees: *Acacia natalitia*, *Schotia afra* var. *afra*. Tall Shrubs: *Chrysanthemoides monilifera* (d), *Elytropappus rhinocerotis* (d), *Olea europaea* subsp. *africana* (d), *Carissa bispinosa* subsp. *bispinosa*, *Clausena anisata*, *Euclea undulata*, *Grewia occidentalis*, *Gymnosporia buxifolia*, *Putterlickia pyracantha*, *Rhus glauca*, *R. laevigata*, *R. longispina*, *R. lucida*, *Tarchonanthus camphoratus*. Low Shrubs: *Pteronia incana* (d), *Anthospermum aethiopicum*, *A. prostratum*, *Aspalathus globulosa*, *Asparagus capensis* var. *capensis*, *A. striatus*, *Athanasia pectinata*, *Felicia filifolia*, *Freylinia undulata*, *Galenia pubescens*, *Garuleum latifolium*, *Gnidia squarrosa*, *Lauridia tetragona*, *Leonotis leonurus*, *Oedera genistifolia*, *Otholobium hirtum*, *Pentzia incana*, *Polygala myrtifolia*, *P. scabra*, *Stoebe muirii*, *Sutera caerulea*. Succulent Shrubs: *Adromischus triflorus*, *Aloe maculata*, *Aptenia cordifolia*, *Cotyledon orbiculata* var. *orbiculata*, *C. papillaris*, *Crassula cultrata*, *Euphorbia burmannii*, *E. mauritanica*, *Lampranthus prominulus, Zygophyllum foetidum*. Woody Succulent Climbers: *Crassula perforata* (d), *Sarcostemma viminale*. Woody Climbers: *Asparagus africanus*, *A. racemosus*. Graminoids: *Ehrharta erecta* (d), *Cynodon dactylon*, *Ehrharta calycina*, *Festuca scabra*, *Karroochloa curva*, *Merxmuellera stricta*, *Panicum maximum*, *Stipa dregeana*. Herbaceous Climber: *Cynanchum obtusifolium*. Succulent Herbs: *Anacampseros telephiastrum*, *Carpobrotus edulis*, *C. muirii*, *Crassula muscosa*, *C. saxifraga*, *Senecio ficoides*. Geophytic Herbs: *Bulbine praemorsa*, *Cheilanthes hirta*, *C. multifida*, *Cyanella lutea*, *Hesperantha acuta*, *Mohria caffrorum*, *Nerine humilis*, *Oxalis bifurca* var. *angustiloba*, *O. obtusa*, *O. pes-caprae*. Herbs: *Arctotheca calendula*, *Berkheya heterophylla*, *Cineraria lobata*, *Cotula sororia*, *Erucastrum austroafricanum*, *Hypoestes aristata*, *Lepidium africanum*, *Lotononis calycina*, *Nemesia fruticans*, *Sebaea ramosissima*, *Sisymbrium capense*, *Stachys aethiopica*.

Biogeographically Important Taxa ([E]Eastern limit, [SE]Southeastern limit, [W]Western limit) Succulent Tree: *Aloe speciosa*[W]. Succulent Shrubs: *Aloe arborescens*[W], *Euphorbia mammillaris*[W], *Portulacaria afra*[W]. Tall Shrubs: *Azima tetracantha*[W], *Diospyros pallens*[SE]. Low Shrub: *Lyperia antirrhinoides*[E]. Succulent Climber: *Crassula lactea*[W]. Succulent Herb: *Gasteria carinata*[SE]. Herb: *Senecio muirii* (shared with AT 2 Gamka Thicket). Graminoid: *Pentaschistis triseta*[E].

Endemic Taxa Succulent Shrub: *Cotyledon eliseae*. Succulent Herbs: *Haworthia chloracantha*, *H. turgida* (all three varieties).

Conservation Vulnerable. Target 19%. Very little of unit conserved in Pauline Bohnen Nature Reserve (statutory) and in Langeberg-Oos Reserve (private). 35% transformed by cultivation. Erosion is variable—from very low to high. Near Albertinia the local *Aloe ferox* has become the subject of a local industry aimed at extracting substances for medicinal and cosmetic use.

Remark 1 This is the westernmost thicket type completely embedded within the matrix of the Fynbos Biome (with a minor border with the Succulent Karoo Biome in the upper Gouritz Valley). A number of taxa reach their westernmost limits of distribution here (see above), suggesting a (past) link to the Albany Thicket proper. At least two species (*Cotyledon papillaris* and *Senecio muirii*) are shared with Gamka Thicket. Not surprisingly, this thicket type contains the highest number of Fynbos elements of the whole Albany Thicket Biome.

Remark 2 The steep, rocky slopes, geomorphology and consequently poor soil development create environmental conditions very different from the surrounding renosterveld vegetation (Fynbos Biome) which typically covers the coastal plateaus of the Southern Cape. The habitats supporting this type of thicket are usually protected from fire that occurs in the neighbouring renosterveld. Grazing by domestic animals was (or in places still is) common.

References Muir (1929), Grobler & Marais (1967), Taylor (1970), Acocks (1988), Rebelo et al. (1991), Cowling & Heijnis (2001), Vlok & Euston-Brown (2002), Vlok et al. (2003).

AT 2 Gamka Thicket

VT 25 Succulent Mountain Scrub (Spekboomveld) (58%) (Acocks 1953). LR 8 Spekboom Succulent Thicket (47%), LR 58 Little Succulent Karoo (20%) (Low & Rebelo 1996, 1998). BHU 97 Spekboom Xeric Succulent Thicket (42%), BHU 89 Oudtshoorn Broken Veld (18%) (Cowling & Heijnis 2001). STEP Gamka Arid Spekboomveld (30%), STEP Kandelaars Karroid Thicket (17%), STEP Mons Ruber Fynbos Thicket (17%) (Vlok & Euston-Brown 2002).

Distribution Western and (marginally) Eastern Cape Provinces. Centred around Oudtshoorn in the basin of the Little Karoo between the Groot Swartberg Mountains in the north and the Outeniqua Mountains in the south, where it occurs on the lower mountain slopes and in some river valleys. It extends from the lower Gamka River Valley and the eastern lower flank of Rooiberg and through the Groot Swartberg Mountains (including the enclosed valley of 'The Hell'), for about 130 km eastwards on lower parts of ridges north of the Groot Swartberg

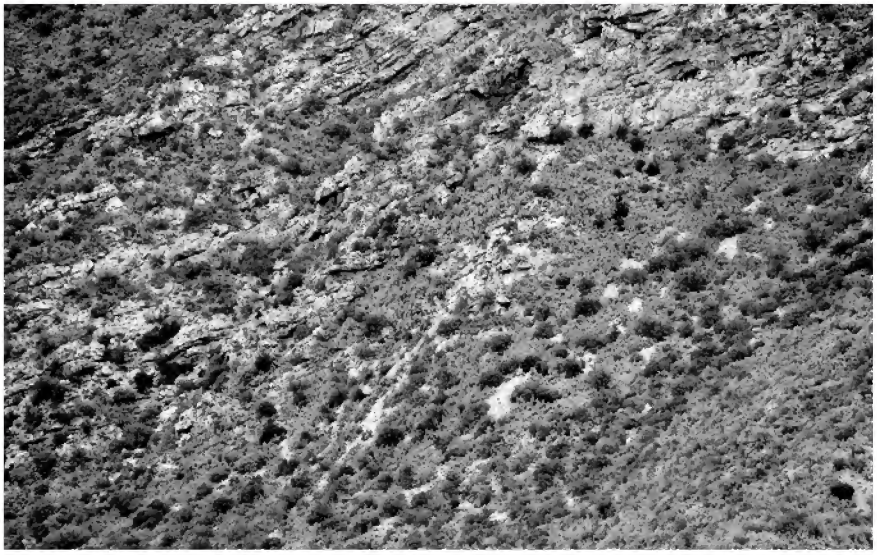


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Figure 10.8 AT 2 Gamka Thicket: Spekboomveld (*Portulacaria afra*) on steep northern slopes of the Huisrivier Pass between Calitzdorp and Ladismith in the Little Karoo (Western Cape).

as far as the Droëkloofberg Mountains (including the isolated ridges to the north that include Tierberg) and to the upper reaches of the Olifants River Valley south of the Groot Swartberg and north of the Kammanassie Mountains. Altitude varies from about 300–1 000 m.

Vegetation & Landscape Features Undulating to steep foothills and valleys dominated by a low succulent thicket, sometimes quite open. In its pristine condition dense stands of spekboom (*Portulacaria afra*) occur, often with *Euclea undulata*, *Gloveria integrifolia*, *Pappea capensis* and *Rhus glauca*. Shrubs are also abundant, stem- and leaf-succulents are often prominent, and the grass component is poorly developed, with *Cenchrus ciliaris, Ehrharta calycina, Eragrostis plana* and *Sporobolus fimbriatus* occasionally abundant after good rain.

Geology & Soils Mostly restricted to sites where relatively deep (>1 m) loamy-clayey soils occur on Enon Formation conglomerates (Jurassic), thus often deep beds of gravelly rocky soil. In the lower Gamka River Valley it occurs on Bokkeveld Group shales and north of the Swartberg Mountains it is found on arenites and shales of the Witteberg, Ecca or Bokkeveld Groups. Land types: mostly Ag (almost half of the area), followed by Ic, Ib and Fc.

Climate The driest of the thicket types, MAP ranges from about 105 mm on the plains north of the Swartberg to about 540 mm (extremes are 102–545 mm) on the south-facing mountain foothills. The rainfall is nonseasonal with slight optima in March and October/November and lowest rainfall in the summer months of December to February. Frost is fairly frequent. Mean monthly maximum and minimum temperatures for Oudtshoorn are 39.9°C and –0.4°C for February and July, respectively. See also climate diagram for AT 2 Gamka Thicket (Figure 10.4).

Important Taxa Succulent Trees: *Aloe ferox*, *A. speciosa*. Small Trees: *Acacia karroo*, *Pappea capensis*, *Schotia afra* var. *afra*. Tall Shrubs: *Cadaba aphylla*, *Carissa bispinosa* subsp. *bispinosa*, *Elytropappus rhinocerotis*, *Dodonaea viscosa* var. *angustifolia*, *Euclea undulata*, *Gymnosporia heterophylla*, *Melianthus comosus*, *Nymania capensis*, *Olea europaea* subsp. *africana*, *Putterlickia pyracantha*, *Rhigozum obovatum*, *Rhus glauca*, *R. lancea*, *R. lucida*. Succulent Shrubs: *Crassula cultrata* (d), *Euphorbia mauritanica* (d), *Portulacaria afra* (d), *Aloe microstigma*, *Cotyledon orbiculata* var. *orbiculata*, *C. papillaris*, *Crassula lanceolata*, *C. nudicaulis*, *C. ovata*, *C. rupestris* subsp. *commutata*, *C. tetragona* subsp. *acutifolia*, *Othonna carnosa*, *Pachypodium succulentum*, *Sceletium rigidum*, *Zygophyllum flexuosum, Z. foetidum*, *Z. fulvum*. Low Shrubs: *Garuleum latifolium* (d), *Pteronia incana* (d), *P. pallens* (d), *Aptosimum indivisum*, *Asparagus burchellii*, *A. mucronatus*, *A. striatus*, *Ballota africana*, *Chrysocoma ciliata*, *Eriocephalus africanus*, *Euryops brevipapposus*, *Felicia filifolia*, *F. muricata*, *Galenia africana*, *Gloveria integrifolia*, *Helichrysum zeyheri*, *Limeum aethiopicum*, *Lycium cinereum*, *L. oxycarpum*, *Monechma spartioides*, *Oedera squarrosa*, *Polygala myrtifolia*, *P. scabra*, *Tetragonia robusta* var. *psiloptera*, *Zygophyllum microphyllum*. Woody Succulent Climbers: *Pelargonium zonale*, *Sarcostemma viminale*. Semiparasitic Epiphytic Shrub: *Viscum rotundifolium*. Woody Climbers: *Asparagus racemosus*, *Cissampelos capensis*. Herbaceous Climbers: *Cynanchum ellipticum*, *Kedrostis capensis*. Graminoids: *Cynodon dactylon* (d), *C. incompletus* (d), *Ehrharta calycina* (d), *Eragrostis curvula* (d), *Aristida adscensionis*, *Cymbopogon prolixus*, *Digitaria argyrograpta*, *D. eriantha*, *Ehrharta erecta*, *Eragrostis obtusa*, *Fingerhuthia africana*, *Hyparrhenia poecilotricha*, *Stipagrostis ciliata* var. *capensis*. Succulent Herbs: *Crassula muscosa*, *Haworthia blackburniae* var. *blackburniae*. Geophytic Herbs: *Oxalis pes-caprae* (d), *Asplenium cordatum*, *Cheilanthes hirta*, *Chlorophytum crispum, Drimia intricata*. Herbs: *Arctotheca calendula*, *Chamaesyce inaequilatera*, *Cineraria platycarpa*, *Conyza scabrida*, *Emex australis*, *Hermannia pulverata*, *Lepidium africanum*, *Pulicaria scabra*, *Troglophyton capillaceum*.

Endemic Taxa Succulent Shrub: *Euphorbia gamkensis*. Geophytic Herbs: *Eriospermum rhizomatum*, *Lachenalia haarlemensis*.

Conservation Least threatened. Target 19%. About 9% statutorily conserved mainly in Groot Swartberg, Groenefontein and Gamkapoort Nature Reserves. About 4% transformed mainly by cultivation. The invasive alien, *Atriplex lindleyi*, is scattered in places. Erosion is very low to moderate. Fragmentation of the Gamka Thicket has occurred due to frequent fires that sweep down from the adjacent fynbos-clad mountains.

Remarks The vegetation has complex floristic and spatial links to Nama-Karoo and Succulent Karoo as well as to the Fynbos Biome vegetation demonstrated by the synonymy with a number of previously described vegetation units (see above). It is particularly in this area that Acocks (1953) characteristically positioned his Spekboomveld (thicket) in a vegetation sequence between the lower lying karoo and higher positioned renosterveld.

References Acocks (1953, 1988), Lloyd et al. (2002), Vlok & Euston-Brown (2002), Vlok et al. (2003), Cleaver et al. (2005).

AT 3 Groot Thicket

VT 25 Succulent Mountain Scrub (Spekboomveld) (43%), VT 26 Karroid Broken Veld (27%) (Acocks 1953). LR 8 Spekboom Succulent Thicket (33%), LR 54 Central Lower Nama Karoo (29%) (Low & Rebelo 1996, 1998). BHU 98 Willowmore Xeric Succulent Thicket (23%), BHU 92 Steytlerville Broken Veld (13%), BHU 73 Baviaanskloof Mountain Fynbos Complex (10%), BHU 99 Addo Xeric Succulent Thicket (9%) (Cowling & Heijnis 2001). STEP Groot Arid Spekboomveld (43%), STEP Baviaans Spekboom Thicket (21%) (Vlok & Euston-Brown 2002).

Distribution Eastern Cape Province: Lower slopes and ridges from Willowmore/Perdepoort in the west to the Klein Winterhoek/Zuurberg Mountains (northwest of Kirkwood) in the east including some narrow northern edges of the Baviaanskloof and Groot Winterhoek Mountains as well as the thicket of the central and upper Baviaanskloof (also narrow tributaries, for example, the Kouga River). Altitude ranges from about 200–1 100 m.

Vegetation & Landscape Features Moderate to steep slopes on the ridges of the mountain ranges dominated by a low succulent thicket, usually fairly dense and closed. Under favourable conditions spekboom (*Portulacaria afra*) is abundant amongst sometimes dense stands of other low woody shrubs. Stem- and leaf-succulents are present and may be prominent, and the grass component is usually poorly developed.

Geology & Soils Commonly found on steep slopes with relatively shallow, red, clayey and often rocky soils that are derived from a variety of parent materials, usually arenites and shales. Geological Groups include Table Mountain, Witteberg, Dwyka and Ecca. The dominant land types are Ib and Fc, followed by Ag and Fb.

Climate Subjected to summer droughts, but regular winter rain may decrease the impact of these droughts. MAP is relatively low, generally 250–450 mm; the rainfall is nonseasonal, with slight optima in March and November. The mean coefficient of variation in MAP is 35% for this vegetation unit; frost incidence varies from about 5 days of frost per annum in the east to around 65 days in the western parts. Mean monthly maximum and minimum temperatures for Willowmore are 37.7°C and –3.1°C for January and July, respectively, although there are smaller extremes in the east than the west. See also climate diagram for AT 3 Groot Thicket (Figure 10.4).

Important Taxa Succulent Trees: *Aloe ferox*, *Euphorbia tetragona*. Small Trees: *Acacia karroo*, *Boscia albitrunca*, *Cussonia spicata*, *Encephalartos lehmannii, Ozoroa mucronata*, *Pappea capensis*, *Schotia afra* var. *afra*, *Sideroxylon inerme*. Tall Shrubs: *Euclea undulata* (d), *Grewia robusta* (d), *Carissa bispinosa* subsp. *bispinosa*, *Dodonaea viscosa* var. *angustifolia*, *Elytropappus rhinocerotis*, *Gymnosporia polyacantha*, *Putterlickia pyracantha*, *Rhigozum obovatum*, *Rhus longispina*, *R. lucida*. Succulent Shrubs: *Crassula cultrata* (d), *C. ovata* (d), *C. rupestris* subsp. *commutata* (d), *Euphorbia ledienii* (d), *Portulacaria afra* (d), *Adromischus cristatus* var. *schonlandii*, *Cotyledon tomentosa* subsp. *tomentosa*, *Crassula tetragona* subsp. *robusta*, *Euphorbia mauritanica*, *E. polygona*, *Glotiphyllum oligocarpum, G. salmii, Pachypodium succulentum*, *Senecio junceus, Zygophyllum foetidum*. Low Shrubs: *Chrysocoma ciliata* (d), *Felicia muricata* (d), *Indigofera denudata* (d), *Aptosimum elongatum*, *Asparagus burchellii*, *A. mucronatus*, *A. subulatus*, *Eriocephalus africanus*, *E. capitellatus*, *E. ericoides*, *Euryops spathaceus, Felicia filifolia*, *Hermannia gracilis*, *Leucas capensis*, *Limeum aethiopicum* (d), *Lycium oxycarpum*, *Monechma spartioides*, *Pteronia adenocarpa*, *P. incana*, *Rosenia humilis*, *Selago albida*, *S. fruticosa*, *Solanum tomentosum*. Semiparasitic Epiphytic Shrub: *Viscum rotundifolium*. Woody Succulent Climbers: *Crassula perforata* (d), *Crassula pellucida* subsp. *marginalis*, *Sarcostemma viminale*. Woody Climbers: *Asparagus racemosus*, *Capparis sepiaria* var. *citrifolia*, *Cissampelos capensis*, *Rhoicissus digitata*. Graminoids: *Aristida adscensionis* (d), *A. congesta* (d), *Cynodon incompletus* (d), *Eragrostis obtusa* (d), *Setaria lindenbergiana* (d), *Tragus berteronianus* (d), *Cenchrus ciliaris*, *Cymbopogon pospischilii*, *Ehrharta calycina*, *Enneapogon desvauxii*, *Eragrostis curvula*, *Merxmuellera stricta*, *Sporobolus fimbriatus*. Succulent Herbs: *Crassula muscosa* (d), *C. orbicularis* (d), *Crassula expansa, Psilocaulon junceum*. Geophytic Herbs: *Asplenium cordatum, Boophone disticha, Moraea pallida*, *Sansevieria hyacinthoides*. Herbs: *Aizoon glinoides* (d), *Troglophyton capillaceum* (d), *Hermannia pulverata*, *Lepidium africanum*, *Pollichia campestris*, *Stachys aethiopica*.

Endemic Taxa Succulent Shrubs: *Aloe pictifolia*. Succulent Herbs: *Huernia brevirostris* subsp. *baviaana*, *H. echidnopsioides*, *Gasteria ellaphieae*, *G. glomerata*, *G. rawlinsonii*, *Haworthia glauca* var. *herrei*, *H. pungens*, *H. zantneriana* var. *minor*, *Stapelia kougabergensis*, *Tromotriche baylissii*, *T. longii*. Geophytic Herbs: *Albuca cremnophila, Bulbine cremnophila*.

Conservation Least threatened. Target 19%. About 11% statutorily conserved mainly in the Greater Addo Elephant National Park, Guerna Wilderness Area and Baviaanskloof Conservation Area. 3.5% conserved in addition in other reserves, for example in the Timbili Game Reserve and Brakkefontein Game Farm. Only about 1.5% transformed mainly through urbanisation and cultivation. Many parts have been opened up by overgrazing and poor management practices and fence-line contrasts along mountain slopes are fairly common, with thicket present on one side and absent on the other. Erosion is generally very low to moderate.

Remarks Although there are several species endemic to the Groot Thicket, many Albany Centre endemics are shared with the Kowie, Gamka, Gamtoos and Sundays Thicket vegetation units. The Thicket vegetation here thus consists of a combination of many of the thicket species that occur within the central portion of the Albany Thicket Biome. Despite having a common denominating content of thicket species, the Groot Thicket units have a unique combination of species and/or have local endemic species present in their mosaic units (Vlok & Euston-Brown 2002). Some of the species present in this unit (e.g. *Euphorbia polygona, E. tetragona, Ozoroa mucronata* and *Plumbago auriculata*) indicate a close affinity to more eastern portions of the Albany Valley Thicket.

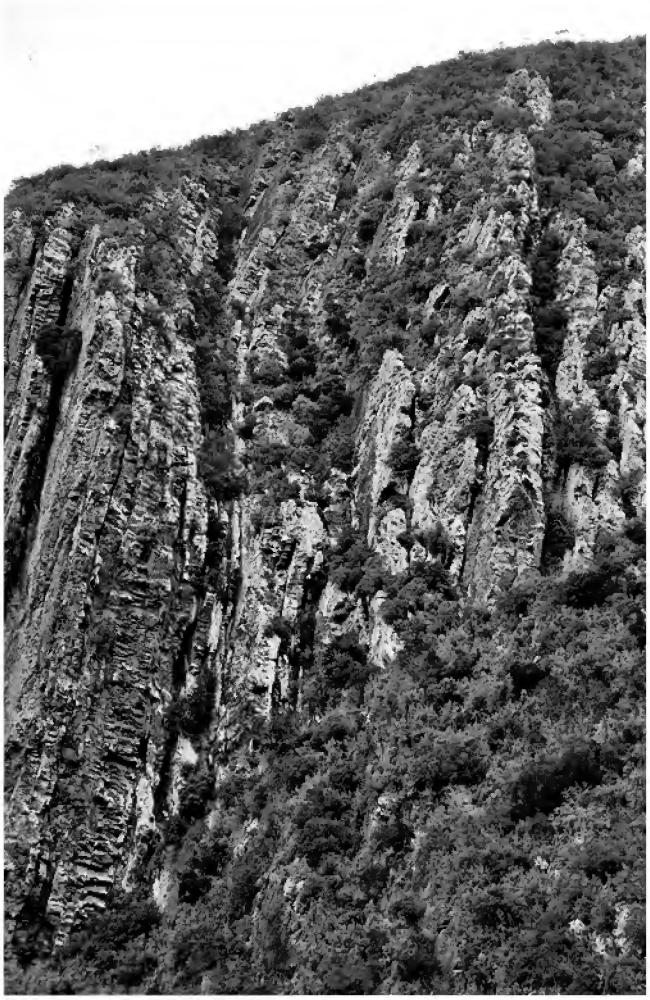
References Acocks (1953, 1988), Lloyd et al. (2002), Vlok & Euston-Brown (2002), Vlok et al. (2003).

AT 4 Gamtoos Thicket

VT 70 False Macchia (42%), VT 23 Valley Bushveld (35%) (Acocks 1953). Valley Bushveld (35%), Mosaic of South Coast Renosterveld (12%), Mesic Grassy Fynbos (11%) (Moll & Bossi 1984). LR 54 Central Lower Nama Karoo (28%), LR 63 South and South-west Coast Renosterveld (22%) (Low & Rebelo 1996, 1998). BHU 92 Steytlerville Broken Veld (27%), BHU 21 Humansdorp Grassy Fynbos (20%), BHU 30 Kromme Fynbos/Renosterveld Mosaic (20%) (Cowling & Heijnis 2001). STEP Gamtoos Valley Thicket (38%), STEP Gamtoos Arid Spekboomveld (20%) (Vlok & Euston-Brown 2002).

Distribution Eastern Cape Province: Coastal basin of the Gamtoos River Valley, south of the Baviaanskloof Mountains and along some smaller river valleys such as that of the Kromme River. Also found north of the Baviaanskloof Mountains in more xeric conditions on some low ridges south and southeast of Steytlerville. Altitude 0–700 m.

Vegetation & Landscape Features On the low mountain slopes in steeply sloping areas and on low ridges. Tall, dense thicket, where both the trees and shrubs and the succulent component are well represented. Few distinct strata can be differentiated within much of the vegetation, as the lower and upper canopy species are intertwined, often together with a wide variety of liana species linking the understorey species with the canopy. Occurs mostly as a fragmented community with large, dense stands restricted to south- and southwest-facing slopes that are protected against fires. The structure of



L. Mucina

Figure 10.9 AT 4 Gamtoos Thicket: Nonsucculent face of Gamtoos Thicket on steep sandstone slopes of the Baviaanskloof River Valley (near Patensie, Eastern Cape).

the dense stands of Gamtoos Thicket is similar to that of the Sundays Thicket, but it differs in the dominant species.

Geology & Soils Mostly restricted to rocky, sandy-loamy soils derived from shale and sandstone of the Bokkeveld Group (Ceres and Tarka Subgroups) and Table Mountain Group (Nardouw Subgroup) as well as the Jurassic Enon conglomerates. Also found are fairly shallow clayey soils derived from the Gamtoos Group limestone, phyllite and arenite of the Kaan and Klein River Formations (Namibian Erathem). Fc land type covers half of the area, followed by Ae and Ib.

Climate Nonseasonal rainfall with slight optima in March and November. MAP ranges from about 180 mm in the northwest inland areas to 850 mm in the southeast coastal sites. The coefficient of variation in MAP is 32% for the unit, but varies from 22% at the coast to 38% inland. The mean daily maximum temperatures for January are 24°C at the coast and 31°C inland and the mean daily minimum temperatures for July are 3°C inland and 9°C at the coast. The incidence of frost is 7 days, but ranging widely from 3 days at the coast to more than 25 days of frost per year inland. See also climate diagram for AT 4 Gamtoos Thicket (Figure 10.4).

Important Taxa Succulent Trees: *Euphorbia triangularis* (d), *Aloe africana*, *A. speciosa*, *Euphorbia grandidens*. Small Trees: *Apodytes dimidiata*, *Canthium spinosum*, *Cussonia spicata*, *C. thyrsiflora*, *Maytenus undata*, *Pappea capensis*, *Ptaeroxylon obliquum*, *Schotia afra* var. *afra*, *Sideroxylon inerme*, *Vepris lanceolata*. Tall Shrubs: *Allophylus decipiens*, *Azima tetracantha*, *Carissa bispinosa* subsp. *bispinosa*, *Crotalaria capensis*, *Ehretia rigida*, *Elytropappus rhinocerotis*, *Euclea racemosa*, *E. undulata*, *Grewia occidentalis*, *Gymnosporia capitata*, *G. heterophylla*, *G. polyacantha*, *Hippobromus pauciflorus*, *Maerua cafra*, *Mystroxylon aethiopicum*, *Nylandtia spinosa*, *Olea europaea* subsp. *africana*, *Pterocelastrus tricuspidatus*, *Putterlickia pyracantha*, *Rhus glauca*, *R. incisa*, *R. longispina*, *R. lucida*, *R. pterota*, *R. refracta*, *Scolopia zeyheri*, *Scutia myrtina*. Low Shrubs: *Felicia muricata* (d), *Anthospermum aethiopicum*, *Asparagus striatus*, *Chaetacanthus setiger*, *Eriocephalus africanus*, *E. algoensis, E. spathaceus, Jamesbrittenia microphylla*, *Lauridia tetragona*, *Oedera genistifolia*, *Phyllanthus maderaspatensis*, *Pteronia incana*, *Senecio linifolius*. Succulent Shrubs: *Portulacaria afra* (d), *Exomis microphylla* var. *axyrioides*, *Cotyledon campanulata*, *C. orbiculata* var. *oblonga*, *C. tomentosa* subsp. *tomentosa*, *Crassula cultrata*, *Delosperma ecklonis*, *Euphorbia mauritanica*, *E. polygona*, *Glottiphyllum linguiforme*, *Senecio oxyodontus*, *Tylecodon striatus, Zygophyllum debile*. Semiparasitic Shrub: *Osyris compressa*. Semiparasitic Epiphytic Shrub: *Viscum rotundifolium*. Woody Climbers: *Capparis sepiaria* var. *citrifolia* (d), *Rhoicissus digitata* (d), *Asparagus aethiopicus*, *A. racemosus*, *Jasminum angulare*, *Plumbago auriculata*, *Rhoiacarpos capensis*. Woody Succulent Climber: *Sarcostemma viminale*. Herbaceous Climbers: *Cynanchum ellipticum*, *Senecio deltoideus*. Graminoids: *Ehrharta calycina* (d), *E. erecta* (d), *Panicum deustum* (d), *Setaria sphacelata* (d), *Aristida congesta*, *Cenchrus ciliaris*, *Cynodon dactylon*, *Digitaria natalensis*, *Enneapogon desvauxii*, *E. scoparius*, *Eragrostis obtusa*, *Eustachys paspaloides*, *Ficinia indica*, *F. nodosa*, *Heteropogon contortus*, *Karroochloa curva*, *Leptochloa fusca*, *Melica racemosa*, *Panicum maximum*, *P. stapfianum*, *Pycreus polystachyos* var. *laxiflorus*, *Sporobolus africanus*, *S. fimbriatus*, *Stipa dregeana*, *Themeda triandra*, *Tribolium hispidum*. Succulent Herbs: *Crassula expansa*, *C. muscosa*, *C. orbicularis*, *Plectranthus grandidentatus*, *P. madagascariensis, Senecio radicans*. Geophytic Herbs: *Asplenium cordatum*, *Bonatea speciosa* var. *antennifera*, *Bulbine alooides*, *B. frutescens*, *Chasmanthe aethiopica, Ornithogalum longibracteatum*, *Oxalis obtusa, Pelargonium pulverulentum, Sansevieria hyacinthoides*. Herbs: *Hypoestes aristata* (d), *Abutilon sonneratianum*, *Acalypha ecklonii*, *Blepharis integrifolia* var. *clarkei*, *Hibiscus pusillus*, *Indigastrum costatum* subsp. *macrum*, *Indigofera hedyantha*, *Peristrophe cernua*, *Stachys aethiopica*.

Endemic Taxa Small Tree: *Cussonia gamtoosensis*. Succulent Herbs: *Huernia bayeri*, *Gasteria pulchra*. Geophytic Herb: *Lachenalia latimerae*.

Conservation Least threatened. Target 19%. A total of 6% of this vegetation unit is protected in statutory conservation areas: Baviaanskloof Conservation Area, Guerna and Berg Plaatz Wilderness Areas as well as Stinkhoutsberg, Kabeljousrivier, Loerie Dam and Seekoeirivier Nature Reserves. Private conservation areas (Hankey Forest Reserve No. 1, Monteaux Game Ranch, Lombardini Game Farm, Kabeljous River Natural Heritage Site, and Kromme River Mouth, Eastcot and Loerie Dam Nature Reserves) also protect some patches of this vegetation type. Some 12% of Gamtoos Thicket has been altered by cultivation and 1% by urbanisation. The alien *Atriplex lindleyi* subsp. *inflata* has invaded many degraded arid thicket areas, especially on soils with a high clay content. Erosion is variable.

Remarks The structural characteristics and species present within the Gamtoos Thicket are intermediate between those of the Sundays River Thicket and Gouritz River Thicket (*sensu* Vlok & Euston-Brown 2002). However, the composition of the dominant species differs and there are several endemic species present in the Gamtoos Thicket, especially in the matrix vegeta-

tion, that only occur as fragmented clumps. The flora that occur along its boundaries is shared and has been enriched by the species typical of the adjacent units (Cowling 1983), e.g. Sundays Thicket. To a degree this is also true for the Baviaanskloof mountain zone, especially where the Gamtoos Thicket unit abuts the boundaries of the Groot Thicket units. Many species typical of both these major regions may co-occur along these overlapping areas, presenting rather diffuse patterns in species gradients (Vlok & Euston-Brown 2002).

References Acocks (1953, 1988), Cowling & Campbell (1983), Cowling (1984), Pierce & Cowling (1984), Everard (1987), Midgley & Cowling (1993), Vlok & Euston-Brown (2002), Vlok et al. (2003), Kamineth (2004).

AT 5 Sundays Noorsveld

VT 24 Noorsveld (72%) (Acocks 1953). LR 6 Xeric Succulent Thicket (84%) (Low & Rebelo 1996, 1998). STEP Sundays Noorsveld (100%) (Vlok & Euston-Brown 2002).

Distribution Eastern Cape Province: Mostly north of the Klein Winterhoek Mountains, centred around Waterford and the Darlington Dam and a smaller area from Jansenville westwards. Also some patches south of this mountain range west of Kirkwood in the Sundays River Valley. Altitude 100–600 m.

Vegetation & Landscape Features Flat lowlands where the vegetation is a dense, usually 1–2 m tall succulent thicket consisting of a mosaic of noors (*Euphorbia caerulescens*) and low karoo shrub vegetation (dominated by *Pentzia incana* and *Rhigozum obovatum*). Punctuated by solitary trees and shrub groups with *Pappea capensis, Euclea undulata, Rhus longispina* and *Gymnosporia polyacantha*.

Geology & Soils Shale, mudstones and sandstones of the Beaufort and Ecca Groups of the Karoo Supergroup in the north as well as of the Mesozoic Uitenhage Group in the south. Often heavy, clayey soils, but may be sandy and of Quaternary origin. The Fc land type overwhelmingly dominates.

Climate Nonseasonal rainfall with slight optima in March and November, but primarily in late summer. MAP ranges from about 210 mm in the west to 320 mm in the east. The incidence of frost is only 5 days, ranging from 3 to 13 days of frost per year. Mean daily maximum and minimum temperatures are 29–32°C and 4–6°C for January and July, respectively, and this is consistent across the distribution of the vegetation type. Mean monthly maximum and minimum temperatures for the Mentz Dam weather station are 41.4°C and –2.2°C for January and July, respectively. See also climate diagram for AT 5 Sundays Noorsveld (Figure 10.4).

Important Taxa Succulent Tree: *Aloe ferox* (d). Small Trees: *Pappea capensis* (d), *Acacia karroo*, *Boscia albitrunca*, *B. oleoides*, *Schotia afra* var. *afra*. Tall Shrubs: *Grewia robusta* (d), *Gymnosporia polyacantha* (d), *Azima tetracantha*, *Cadaba aphylla*, *Carissa bispinosa* subsp. *bispinosa*, *Diospyros austro-africana*, *Euclea undulata*, *Gymnosporia capitata*, *Nymania capensis*, *Putterlickia pyracantha*, *Rhus longispina*. Low Shrubs: *Blepharis capensis* (d), *Jamesbrittenia microphylla* (d), *Lycium cinereum* (d), *L. oxycarpum* (d), *Pentzia incana* (d), *Rhigozum obovatum* (d), *Aptosimum elongatum*, *Asparagus burchellii*, *A. crassicladus*, *A. striatus*, *A. suaveolens*, *A. subulatus*, *Barleria pungens*, *B. rigida*, *Chrysocoma ciliata*, *Eriocephalus ericoides*, *Felicia filifolia*, *F. muricata*, *Garuleum latifolium*, *Helichrysum rosum*, *H. zeyheri*, *Hermannia althaeoides*, *H. gracilis*, *Indigofera sessilifolia*, *Lantana rugosa*, *Leucas capensis*, *Lepidium africanum*, *Limeum aethiopicum*, *Monechma pseudopatulum*, *M. spartioides*, *Pelargonium aridum*, *Phyllanthus verrucosus*, *Phymaspermum parvifolium*, *Polygala seminuda*, *Rosenia humilis*, *Selago albida*, *S. fruticosa*, *S. triquetra*, *Solanum capense*, *S. tomentosum*. Succulent Shrubs: *Euphorbia caerulescens* (d), *Adromischus cristatus* var. *schonlandii*, *Aloe lineata*, *A. striata*, *Cotyledon orbiculata* var. *oblonga*, *C. velutina*, *C. woodii*, *Crassula corallina* subsp. *corallina*, *C. ovata*, *Delosperma frutescens*, *Drosanthemum lique*, *Euphorbia esculenta*, *E. mauritanica*, *E. pentagona*, *Mestoklema tuberosum*, *Pachypodium succulentum*, *Portulacaria afra*, *Trichodiadema barbatum*. Semiparasitic Shrub: *Thesium junceum*. Semiparasitic Epiphytic Shrubs: *Viscum continuum*, *V. obscurum*, *V. rotundifolium*. Woody Succulent Climber: *Sarcostemma viminale*. Woody Climbers: *Asparagus racemosus*, *Cissampelos capensis*, *Rhoicissus digitata*. Graminoids: *Aristida adscensionis* (d), *A. congesta* (d), *Cenchrus ciliaris* (d), *Cynodon incompletus* (d), *Ehrharta erecta* (d), *Eragrostis obtusa* (d), *Tragus berteronianus* (d), *Aristida barbicollis*, *A. diffusa*, *Chloris virgata*, *Cynodon dactylon*, *Digitaria argyrograpta*, *Ehrharta calycina*, *Enneapogon desvauxii*, *E. scoparius*, *Eragrostis chloromelas*, *E. curvula*, *E. lehmanniana*, *Fingerhuthia africana*, *Heteropogon contortus*, *Oropetium capense*, *Panicum coloratum*, *P. deustum*, *P. maximum*, *Setaria verticillata*, *Sporobolus fimbriatus*, *Tragus racemosus*. Herbaceous Climbers: *Cynanchum ellipticum*, *C. gerrardii*, *Cyphia sylvatica*, *Kedrostis capensis*, *K. nana*. Succulent Herbs: *Mesembryanthemum aitonis* (d), *C. muscosa*, *Gasteria maculata*, *Mesembryanthemum crystallinum*, *Senecio radicans*. Geophytic Herbs: *Drimia intricata* (d), *D. anomala*, *Ledebouria undulata*, *Moraea polystachya*, *Oxalis stellata*, *Sansevieria aethiopica*, *Tritonia laxifolia*. Herbs: *Aizoon glinoides* (d), *Gazania krebsiana* (d), *Lasiopogon glomerulatus* (d), *Lotononis leptoloba* (d), *Abutilon sonneratianum*, *Amaranthus thunbergii*, *Boerhavia diffusa*, *Chamaesyce inaequilatera*, *Cucumis myriocarpus*, *Hermannia cernua*, *H. comosa*, *H. pulverata*, *Hibiscus pusillus*, *Indigastrum costatum* subsp. *macrum*, *Indigofera disticha*,

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Figure 10.10 AT 5 Sundays Noorsveld: Low succulent thicket with *Euphorbia caerulescens* (Euphorbiaceae) north of Wolwefontein on the road to Jansenville in the Sundays River basin (Eastern Cape).

Isoglossa ciliata, *Lactuca dregeana*, *L. desertorum*, *Lessertia pauciflora*, *Leysera tenella*, *Lotononis calycina*, *Peucedanum typicum*, *Tetragonia echinata*, *T. microptera*, *Tribulus terrestris*. Parasitic Herb: *Hydnora africana*.

Conservation Least threatened. Target 19%. Almost 15% statutorily conserved in Greater Addo Elephant National Park and some 3% in private game ranches (Kuzuko, Voetpadskloof, Koedoeskop, Schuilpatdop Game Farm, Goodhope). About 4% transformed with cultivation the primary factor. Erosion is moderate to very low.

References Acocks (1953, 1988), Van der Walt (1965), Hoffman (1989a, b), Hoffman & Cowling (1990), Du Toit & Blom (1995), Vlok & Euston-Brown (2002), Vlok et al. (2003).

AT 6 Sundays Thicket

VT 23 Valley Bushveld (42%), VT 24 Noorsveld (28%) (Acocks 1953). LR 6 Xeric Succulent Thicket (57%) (Low & Rebelo 1996, 1998). STEP Sundays Spekboomveld (55%) (Vlok & Euston-Brown 2002).

Distribution Eastern Cape Province: From the surrounds of Uitenhage and the northern edge of Port Elizabeth into the lower Sundays River Valley to east of Colchester and northwards to the base of the Zuurberg Mountains and stretching westwards north of the Groot Winterhoek Mountains to roughly the Kleinpoort longitude. Also an extensive area north of the Klein Winterhoek Mountains including much of the Jansenville District and parts of the far-southern Pearston District and far-western Somerset East District. Altitude 0–800 m.

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Figure 10.11 AT 6 Sundays Thicket: Dense thicket with *Euphorbia triangularis* (Euphorbiaceae) and *Cussonia spicata* (Araliaceae) along road from Addo to Zuurberg Inn (Eastern Cape).

Vegetation & Landscape Features Undulating plains and low mountains and foothills covered with tall, dense thicket, where trees, shrubs and succulents are common, with many spinescent species. The transition between lower and upper canopies is obscured by the presence of a wide variety of lianas. The local dominance of *Portulacaria afra* increases and the relative abundance of woody species present decreases with increasing aridity. There is considerable structural heterogeneity within this vegetation unit.

Geology & Soils Mostly on deep (>1 m) red, loamy to clayey soils derived from the Sundays River and Kirkwood Formations (Mesozoic Uitenhage Group) in the south. In the Zuurberg Mountains, soils are more sandy and nutrient-poor and derived from the Bokkeveld and Witteberg Groups (Cape Supergroup). In the inland region of the Sundays River the soils are derived from Ecca Group shales and mudstones, and are heavy due to high clay content. Fc land type dominates the area, followed by Ae.

Climate Nonseasonal rainfall with slight optima in March and October/November. MAP ranges from about 190 mm in the northwest to 480 mm in the southeast on the coast near Port Elizabeth. The coefficient of variation in MAP is 29–38%, increasing with distance inland in a northwesterly direction. The incidence of frost is 8 days, but ranging widely from 3 days near the coast in the southeast to more than 24 days of frost per year in the more inland sites in the northwest. Mean monthly maximum and minimum temperatures for Jansenville are 41.3°C and –0.8°C for January and July, respectively, and corresponding values for Addo are 39.0°C and –0.3°C and for Uitenhage are 36.9°C and 1.3°C, both for February and July, respectively. See also climate diagram for AT 6 Sundays Thicket (Figure 10.4).

Important Taxa Succulent Trees: *Aloe africana* (d), *A. ferox*, *Euphorbia grandidens*. Small Trees: *Pappea capensis* (d), *Schotia afra* var. *afra* (d), *Acacia natalitia*, *Boscia albitrunca*, *Brachylaena ilicifolia*, *Cussonia spicata*, *Encephalartos lehmannii*, *Ptaeroxylon obliquum*, *Sideroxylon inerme*. Tall Shrubs: *Euclea undulata* (d), *Olea europaea* subsp. *africana* (d), *Azima tetracantha*, *Cadaba aphylla*, *Carissa bispinosa* subsp. *bispinosa*, *Diospyros pallens*, *Ehretia rigida*, *Grewia occidentalis*, *G. robusta*, *Gymnosporia buxifolia*, *G. capitata*, *G. polyacantha*, *Maerua cafra*, *Mystroxylon aethiopicum*, *Nymania capensis*, *Putterlickia pyracantha*, *Rhus incisa*, *R. longispina*, *Scutia myrtina*. Low Shrubs: *Pentzia globosa* (d), *Aptosimum elongatum*, *Asparagus burchellii*, *A. crassicladus*, *A. striatus*, *A. subulatus*, *Barleria obtusa*, *B. rigida*, *Blepharis capensis*, *Chascanum cuneifolium*, *Chrysocoma ciliata*, *Eriocephalus ericoides*, *Euryops algoensis*, *E. spathaceus*, *Felicia muricata*, *Garuleum latifolium*, *Hermannia althaeoides*, *Hibiscus aridus*, *Indigofera sessilifolia*, *Justicia orchioides*, *Lantana rugosa*, *Leucas capensis*, *Limeum aethiopicum*, *Lycium oxycarpum*, *Osteospermum imbricatum*, *Pteronia paniculata*, *Rhigozum obovatum*, *Rosenia humilis*, *Selago fruticosa*, *S. geniculata*, *Senecio linifolius*, *Solanum capense*, *S. tomentosum*. Succulent Shrubs: *Crassula ovata* (d), *Euphorbia caerulescens* (d), *E. ledienii* (d), *Portulacaria afra* (d), *Adromischus cristatus* var. *cristatus*, *A. sphenophyllus*, *Cotyledon campanulata*, *C. orbiculata* var. *oblonga*, *Crassula capitella* subsp. *capitella*, *C. capitella* subsp. *thyrsiflora*, *C. cotyledonis*, *C. cultrata*, *C. mesembryanthoides* subsp. *hispida*, *C. rogersii*, *Delosperma echinatum*, *D. uniflorum*, *Euphorbia mauritanica*, *Exomis microphylla*, *Kalanchoe rotundifolia*, *Lampranthus productus*, *Mestoklema tuberosum*, *Orbea pulchella*, *Pachypodium succulentum*, *Pelargonium carnosum*, *Psilocaulon articulatum*, *Zygophyllum foetidum*. Semiparasitic Shrub: *Osyris compressa*. Semiparasitic Epiphytic Shrubs: *Viscum crassulae*, *V. obscurum*, *V. rotundifolium*.

Woody Succulent Climbers: *Pelargonium peltatum* (d), *Crassula perforata*, *Cyphostemma quinatum*, *Sarcostemma viminale*. Woody Climbers: *Asparagus asparagoides*, *A. multiflorus*, *A. racemosus*, *A. volubilis*, *Behnia reticulata*, *Capparis sepiaria* var. *citrifolia*, *Cissampelos capensis*, *Plumbago auriculata*, *Rhoiacarpos capensis*, *Rhoicissus digitata*. Herbaceous Climbers: *Cynanchum ellipticum*, *Kedrostis capensis*. Graminoids: *Aristida adscensionis* (d), *A. congesta* (d), *Cynodon dactylon* (d), *C. incompletus* (d), *Eragrostis obtusa* (d), *Panicum maximum* (d), *Tragus berteronianus* (d), *Cenchrus ciliaris*, *Cyperus capensis*, *Digitaria argyrograpta*, *Ehrharta calycina*, *Enneapogon scoparius*, *Eragrostis curvula*, *Eustachys paspaloides*, *Heteropogon contortus*, *Panicum deustum*, *Sporobolus fimbriatus*, *Stipa dregeana*, *Themeda triandra*. Succulent Herbs: *Senecio radicans* (d), *Crassula expansa*, *C. spathulata*, *Gasteria bicolor*, *Sansevieria aethiopica*. Geophytic Herbs: *Bulbine frutescens* (d), *Drimia intricata* (d), *Sansevieria hyacinthoides* (d), *Cyanella lutea*, *Cyrtanthus loddigesianus*, *C. spiralis*, *Drimia anomala*, *Freesia corymbosa*, *Hypoxis argentea*, *Justicia cuneata* subsp. *cuneata*, *Moraea stricta*, *Oxalis smithiana*, *Spiloxene trifurcillata*, *Trachyandra affinis*, *Tritonia securigera*, *Tritonia strictifolia*, *Urginea altissima*. Herbs: *Abutilon sonneratianum*, *Aizoon glinoides*, *Arctotheca calendula*, *Chamaesyce inaequilatera*, *Commelina benghalensis*, *Cotula heterocarpa*, *Cyanotis speciosa*, *Cypselodontia eckloniana*, *Emex australis*, *Gazania krebsiana*, *Hibiscus pusillus*, *Hypoestes aristata*, *Indigastrum costatum* subsp. *macrum*, *Lepidium africanum*, *Lotononis glabra*, *Stachys aethiopica*.

Biogeographically Important Taxa (^{S}Southern limit) Succulent Climber: *Ceropegia ampliata* var. *ampliata*^{S}. Herbaceous Climber: *Fockea sinuata*^{S}. Epiphytic Parasitic Herb: *Cuscuta bifurcata*. Geophytic Herb: *Pelargonium campestre*.

Endemic Taxa Small Tree: *Encephalartos horridus*. Succulent Shrubs: *Aloe bowiea*, *A. gracilis*, *Bergeranthus addoensis*, *Glottiphyllum grandiflorum*, *Orthopterum coegana*, *Ruschia aristata*, *Trichodiadema rupicola*. Succulent Climbers: *Aptenia haeckeliana*, *Ceropegia dubia*. Succulent Herbs: *Haworthia arachnoidea* var. *xiphiophylla*, *H. aristata*, *Huernia longii* subsp. *longii*. Geophytic Herbs: *Brachystelma cummingii*, *B. schoenlandianum*, *B. tabularium*, *Pelargonium ochroleucum*, *Strelitzia juncea*, *Tritonia dubia*. Herbs: *Arctotis hispidula*, *Argyrolobium crassifolium*, *Lessertia carnosa*, *Lotononis monophylla*, *Senecio scaposus* var. *addoensis*, *Wahlenbergia oocarpa*.

Conservation Least threatened. Target 19%. Protected statutorily in Greater Addo Elephant National Park, Groendal Wilderness Area as well as in Swartkops Valley and Springs Nature Reserves. Private conservation areas, especially game farms (Kuzuko, Koedoeskop, Schuilpatdop, Tregathlyn, Citruslandgoed, Voetpadskloof) and a couple of nature reserves contribute to conservation of this vegetation type as well. More than 6% already transformed (cultivated, urban development). Sundays Thicket has also been highly degraded through grazing by livestock (Hoffman & Cowling 1990, 1991, Lloyd et al. 2002, Lechmere-Oertel 2003). The degraded state resembles a secondary thornveld or grassland, dominated by invasive weedy species. In this state, most of the original thicket species are lost. Erosion is moderate to very low.

Remarks The considerable research interest in the Sundays Thicket unit is linked to the popular Addo National Park (now encompassing also the former Zuurberg National Park and a series of inland and coastal nature reserves forming the Greater Addo Elephant National Park)—the only locality in the Cape housing an extant population of elephant (*Loxodonta africana*) and an indigenous population of Cape buffalo (*Synceros caffer*).

References Archibald (1955), Pentzhorn & Olivier (1974), Pentzhorn et al. (1974), Aucamp (1976, 1979), Cowling (1983, 1984), Aucamp & Tainton (1984), Everard (1987), Hoffman (1989a, b), Hoffman & Cowling (1990, 1991), La Cock (1992), Stuart-Hill (1992), Midgley & Cowling (1993), Stuart-Hill & Aucamp (1993), Johnson (1998), Johnson et al. (1999), Kerley et al. (1999a, b), Sigwela (1999), Lombard et al. (2001), Todkill (2001), Cowling & Kerley (2002), Lloyd et al. (2002), Vlok & Euston-Brown (2002), Lechmere-Oertel (2003), Vlok et al. (2003), Sigwela et al. (2004).

AT 7 Coega Bontveld

VT 23 Valley Bushveld (87%) (Acocks 1953). Valley Bushveld (98%) (Moll & Bossi 1984). LR 7 Mesic Succulent Thicket (72%) (Low & Rebelo 1996, 1998). BHU 95 Sundays Mesic Succulent Thicket (70%) (Cowling & Heijnis 2001). STEP Grass Ridge Bontveld (100%) (Vlok & Euston-Brown 2002).

Distribution Eastern Cape Province: Northeast of Port Elizabeth just inland of Algoa Bay; mainly around Coega, but also in small patches in Addo (Zuurkop; Pentzhorn & Olivier 1974). Altitude 0–400 m.

Vegetation & Landscape Features On moderately undulating plains, where a mosaic of low thicket (2–3 m) built mainly of bush clumps occurs. Secondary open grassland occurs over wide stretches. This unit is often restricted to 'islands' in a matrix of typical valley thicket. The species present are a mixture of Fynbos, Grassland and Succulent Karoo elements.

Geology & Soils Outcrops of limestone (Nanaga Formation), and calcareous paleo-dune fields of the Cenozoic Algoa Group. The soils are shallow clay soils that are often lime-rich. Most of the area of this unit is primarily classified as the Fc land type, with Ae land type of minor importance.

Climate Nonseasonal rainfall with optima in March and October. MAP ranges from about 400 mm inland in the west to 550 mm in the east and closer to the coast. The coefficient of variation in MAP ranges between 30% and 32%. The incidence of frost is only 3 days, not varying across the range of the vegetation unit. Mean monthly maximum and minimum temperatures for the nearby Port Elizabeth are 32.1°C and 3.4°C for February and July, respectively. See also climate diagram for AT 7 Coega Bontveld (Figure 10.4).

Important Taxa Succulent Trees: *Aloe africana*, *A. ferox*. Small Trees: *Schotia afra* var. *afra*, *Sideroxylon inerme*. Tall Shrubs: *Euclea undulata* (d), *Carissa bispinosa* subsp. *bispinosa*, *Dovyalis caffra*, *Ehretia rigida*, *Euclea crispa*, *Gymnosporia capitata*, *Hippobromus pauciflorus*, *Maerua cafra*, *Mystroxylon aethiopicum*, *Pterocelastrus tricuspidatus*, *Putterlickia pyracantha*, *Rhus longispina*, *R. lucida*, *R. pyroides* var. *gracilis*, *Scutia myrtina*. Low Shrubs: *Helichrysum anomalum* (d), *Jamesbrittenia microphylla* (d), *Tephrosia capensis* var. *acutifolia* (d), *Acmadenia obtusata*, *Agathosma capensis*, *Asparagus falcatus*, *A. multiflorus*, *A. striatus*, *Blepharis capensis*, *Chaetacanthus setiger*, *Chascanum cuneifolium*, *Clutia daphnoides*, *Disparago ericoides*, *Felicia muricata*, *Hermannia althaeoides*, *H. flammea*, *H. holosericea*, *Lantana rugosa*, *Limeum aethiopicum*, *Lobostemon trigonus*, *Muraltia squarrosa*, *Osteospermum imbricatum*, *O. polygaloides*, *Passerina rubra*, *Wahlenbergia tenella*. Succulent Shrubs: *Crassula expansa* (d), *Ruschia hamata* (d), *Aloe arborescens*, *Carpobrotus edulis*, *Crassula capitella* subsp. *capitella*, *C. ericoides*, *C. perfoliata*, *C. perforata*, *C. tetragona* subsp. *robusta*. Semiparasitic Shrub: *Osyris compressa*. Woody Succulent Climbers: *Pelargonium peltatum*, *Sarcostemma viminale*. Woody Climbers: *Asparagus racemosus*, *Jasminum angulare*, *Rhoiacarpos capensis*, *Rhoicissus digitata*. Herbaceous Climber: *Kedrostis capensis*. Graminoids: *Aristida diffusa* (d), *Cynodon dactylon* (d), *C. incompletus* (d), *Eustachys paspaloides* (d), *Heteropogon contortus* (d), *Merxmuellera disticha* (d), *Panicum maximum* (d), *Setaria sphacelata* (d), *Stipa*

dregeana (d), *Themeda triandra* (d), *Cymbopogon marginatus*, *C. pospischilii*, *Digitaria argyrograpta*, *D. natalensis*, *Ehrharta calycina*, *E. erecta*, *Eragrostis capensis*, *E. curvula*, *E. obtusa*, *Helictotrichon capense*, *Melica racemosa*, *Panicum deustum*, *Pentaschistis pallida*, *Sporobolus ioclados*. Succulent Herbs: *Mesembryanthemum aitonis* (d), *C. muscosa*, Geophytic Herbs: *Sansevieria hyacinthoides* (d), *Bulbine favosa, B. inamarxiae*. *Moraea pallida*, *Oxalis smithiana*. Herbs: *Aizoon rigidum* (d), *Gazania krebsiana* (d), *Hypoestes aristata* (d), *Indigastrum costatum* subsp. *macrum* (d), *Senecio burchellii* (d), *Sutera campanulata* (d), *Arctotheca calendula*, *Berkheya heterophylla*, *Gazania jurineifolia*, *Hibiscus pusillus*, *Lotononis glabra*, *Monsonia emarginata*, *Scabiosa albanensis*.

Biogeographically Important Taxa ([E]Eastern limit, [W]Western limit) Graminoids: *Ficinia truncata*[E], *Tribolium uniolae*[W] (d). Herb: *Gibbaria scabra*[E].

Endemic Taxa Succulent Shrubs: *Euphorbia globosa*, *Rhombophyllum rhomboideum*. Low Shrub: *Anginon rugosum*. Geophytic Herb: *Ledebouria* sp. nov. *('coriacea'* S. Venter ined.).

Conservation Target 19%. A total of 10% of this vegetation unit is protected in the Greater Addo Elephant National Park and almost 4% in the private Grassridge Nature Reserve. Some 4% of Coega Bontveld has been altered by cultivation and 2% by urbanisation. The recent building of the traffic infrastructure around the new harbour near Port Elizabeth has encroached heavily into the area of the Coega Bontveld and the construction of an Industrial Development Zone in the area constitutes a serious threat to this vegetation type. Erosion is moderate to low.

Remarks There are areas in the Eastern Cape north and east of Grahamstown where calcrete resists weathering to form relatively flat landscapes surrounded by eroded valleys. The calcrete in these areas breaks down to form white clay that has been commercially harvested in the past for the production of crockery and pottery. The vegetation in all these areas is structurally and floristically similar to Coega Bontveld and they contain a number of taxa with Cape links, e.g. *Agathosma ovata*. There are also floristic links of Coega Bontveld to the local dune thicket vegetation.

References Acocks (1953, 1988), Pentzhorn & Olivier (1974), Vlok & Euston-Brown (2002), Vlok et al. (2003).

AT 8 Kowie Thicket

VT 23 Valley Bushveld (44%), VT 7 Eastern Province Thornveld (29%) (Acocks 1953). Valley Bushveld (93%) (Moll & Bossi 1984). LR 6 Xeric Succulent Thicket (25%), LR 16 Eastern Thorn Bushveld (24%), LR 5 Valley Thicket (21%) (Low & Rebelo 1996, 1998). STEP Albany Valley Thicket (38%), STEP Albany Thicket (31%) (Vlok & Euston-Brown 2002).

Distribution Eastern Cape Province: In the river valleys of the Bushmans, Kariega, Kowie, Kleinemonde and Kap Rivers from near the Great Fish River Mouth to Kenton-on-Sea, extending inland up these valleys past Grahamstown to just past Riebeeck East and Alicedale to north of the Zuurberg. Altitude 0–700 m.

Vegetation & Landscape Features On mainly steep and north-facing (dry) slopes. Tall thickets dominated by succulent euphorbias and aloes with a thick understorey composed of thorny shrubs, woody lianas (*Capparis, Secamone, Rhoicissus, Aloe*), and shrubby succulents (Crassulaceae, Asphodelaceae). Moister south-facing slopes support thorny thickets dominated by low evergreen trees (*Cussonia, Euclea, Hippobromus, Pappea, Ptaeroxylon, Schotia*) and shrubs (*Azima, Carissa, Gymnosporia, Putterlickia*) with fewer succulent shrubs and trees. The herbaceous layer is poorly developed.

Geology & Soils Clayey soils over Weltevrede and Lake Mentz (Darlington Dam) Formation sandstone and shale (Witteberg Group) and on Dwyka tillite (early Karoo) as well as Algoa Group calcareous sandstone in the south. Occurs on a wide variety of land types including Fc, Fa, Ae and Fb.

Climate Nonseasonal rainfall with optima in March and October/November. MAP ranges from around 340 mm in the west (north of the Zuurberg) to 650 mm in the east (at the coast near Port Alfred). The coefficient of variation in MAP is 30%, but varies from 27% at the coast to 34% inland. The incidence of frost is only 3 days, but ranges from 0 days at the coast to more than 17 days of frost per year inland. Mean monthly maximum and minimum temperatures for Bathurst are 35.0°C and 5.6°C for February and July, respectively. See also climate diagram for AT 8 Kowie Thicket (Figure 10.4).

Important Taxa Succulent Trees: *Euphorbia grandidens* (d), *E. tetragona* (d), *E. triangularis* (d), *Aloe africana*, *A. speciosa*. Small Trees: *Schotia afra* var. *afra* (d), *Acacia natalitia*, *Brachylaena ilicifolia*, *Commiphora harveyi*, *Cussonia spicata*, *Elaeodendron croceum*, *Encephalartos altensteinii*, *E. latifrons*, *E. trispinosus*, *Maytenus undata*, *Pappea capensis*, *Ptaeroxylon obliquum*, *Schotia latifolia*, *Sideroxylon inerme*. Tall Shrubs: *Azima tetracantha* (d), *Croton rivularis* (d), *Gymnosporia polyacantha* (d), *Scutia myrtina* (d), *Acokanthera oppositifolia*, *Allophylus decipiens*, *Calpurnia aurea*, *Carissa bispinosa* subsp. *bispinosa*, *Clausena anisata*, *Coddia rudis*, *Ehretia rigida*,

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Figure 10.12 AT 8 Kowie Thicket: Dense *Euphorbia triangularis*-dominated thicket on slopes facing the Settlers Dam in the Thomas Baines Nature Reserve (near Grahamstown, Eastern Cape).

Euclea undulata, *Flueggea verrucosa*, *Grewia occidentalis*, *Gymnosporia capitata*, *G. heterophylla*, *Hippobromus pauciflorus*, *Maerua cafra*, *Mystroxylon aethiopicum*, *Olea europaea* subsp. *africana*, *Putterlickia pyracantha*, *Rhus longispina*, *R. lucida*, *R. pyroides* var. *gracilis*, *R. refracta*, *Scolopia zeyheri*. Low Shrubs: *Asparagus striatus*, *A. subulatus*, *Chrysocoma ciliata*, *Galenia secunda*, *Hermannia althaeoides*, *Leonotis ocymifolia*, *Limeum aethiopicum*, *Pavonia praemorsa*, *Pelargonium odoratissimum*, *Polygala myrtifolia*, *Pteronia incana*, *Selago fruticosa*, *Senecio linifolius*, *Solanum rigescens*. Succulent Shrubs: *Aloe arborescens* (d), *Crassula cultrata* (d), *Portulacaria afra* (d), *Aptenia cordifolia*, *Bergeranthus scapiger*, *Cotyledon orbiculata* var. *oblonga*, *C. velutina*, *Crassula muscosa*, *C. tetragona* subsp. *acutifolia*, *Delosperma ecklonis*, *Euphorbia kraussiana*, *Exomis microphylla* var. *axyrioides*, *Kalanchoe rotundifolia*, *Mestoklema tuberosum*, *Senecio oxyodontus*. Semiparasitic Epiphytic Shrubs: *Viscum obscurum*, *V. rotundifolium*. Woody Succulent Climbers: *Pelargonium peltatum* (d), *Sarcostemma viminale* (d), *Aloe ciliaris*, *Crassula perforata*, *Senecio macroglossus*. Woody Climbers: *Capparis sepiaria* var. *citrifolia* (d), *Plumbago auriculata* (d), *Asparagus aethiopicus*, *A. multiflorus*, *A. racemosus*, *Dalechampia capensis*, *Ficus burtt-davyi*, *Jasminum angulare*, *Rhoiacarpos capensis*, *Rhoicissus digitata*, *Secamone filiformis*. Herbaceous Climbers: *Acharia tragodes*, *Cynanchum ellipticum*, *Cyphia sylvatica*, *Didymodoxa caffra*, *Senecio deltoideus*. Graminoids: *Cynodon dactylon* (d), *C. incompletus* (d), *Cyperus albostriatus* (d), *Ehrharta erecta* (d), *Eragrostis curvula* (d), *Karroochloa curva* (d), *Panicum deustum* (d), *Setaria sphacelata* (d), *Sporobolus fimbriatus* (d), *Themeda triandra* (d), *Cyperus textilis*, *Eragrostis obtusa*, *Melica racemosa*, *Panicum maximum*. Megaherb: *Dracaena aletriformis*. Succulent Herbs: *Plectranthus grandidentatus* (d), *Crassula expansa, Gasteria bicolor*, *Plectranthus madagascariensis*, *P. verticillatus, Senecio radicans*. Geophytic Herbs: *Sansevieria aethiopica* (d), *S. hyacinthoides* (d), *Asplenium cordatum*, *Bulbine frutescens*, *Cheilanthes hirta*, *Strelitzia reginae, Veltheimia bracteata*. Herbs: *Achyranthes aspera* (d), *Commelina benghalensis* (d), *Hypoestes aristata* (d), *Leidesia procumbens* (d), *Abutilon sonneratianum*, *Centella asiatica*, *Commelina africana*, *Conyza scabrida*, *Ecbolium flanaganii*, *Emex australis*, *Lepidium africanum*, *Phyllopodium cuneifolium*, *Senecio burchellii*, *Sida ternata*, *Tetragonia microptera*, *Troglophyton capillaceum*.

Endemic Taxa Succulent Herb: *Faucaria nemorosa*. Geophytic Herb: *Albuca crudenii*. Herb: *Wahlenbergia kowiensis*.

Conservation Least threatened. Target 19%. A total of 5% of this vegetation unit is protected in various statutory reserves, including the Water's Meeting, Kowie, Cycad, Blaauwkrantz, Kap River Nature Reserves. A further 14% is conserved in private conservation areas such as game ranches (Shamwari, Emlanjeni, Amakhala, Fourie Safaris, Hunters Lodge, Elephant Park and Schotia Safaris) and in the Aylesbury Nature Reserve. Transformation 7%, mainly by cultivation. Erosion is moderate to very low.

Remarks This is bioclimatically the core of the Albany Thicket Biome and the major floristic node of the Albany Centre of Endemism. It is located adjacent to a wide variety of other vegetation types, including Zuurberg Quartzite Fynbos, Zuurberg Shale Fynbos, Southern Coastal Forest, Albany Coastal Belt, Albany Broken Veld, Great Fish Noorsveld and Eastern Cape Thornveld. This indicates the varying floristic influences on this vegetation and many species from different vegetation types may co-occur along these overlapping areas.

References Dyer (1937), Acocks (1953, 1988), Vlok & Euston-Brown (2002), Vlok et al. (2003), Kamineth (2004).

AT 9 Albany Coastal Belt

VT 1 Coastal Forest and Thornveld (29%), VT 2 Alexandria Forest (29%) (Acocks 1953). Valley Bushveld (73%) (Moll & Bossi 1984). LR 16 Eastern Thorn Bushveld (33%), LR 48 Coastal Grassland (21%) (Low & Rebelo 1996, 1998). STEP Berlin Savanna Thicket (22%), STEP Grahamstown Grassland Thicket (14%), STEP Hamburg Dune Thicket (11%), STEP Paterson Savanna Thicket (7%) (Vlok & Euston-Brown 2002).

Distribution Eastern Cape Province: Within 15 km (sometimes up to 30 km) of the Indian Ocean coastline, from Kei Mouth to the Sundays River, interrupted by many valleys. Altitude 10–400 m.

Vegetation & Landscape Features On the gently to moderately undulating landscapes and dissected hilltop slopes close to the coast, dominated by short grasslands punctuated by scattered bush clumps or solitary *Acacia natalitia* trees.

Geology & Soils The area covered by this unit is geologically complex and includes Beaufort Group mudstone and sandstone in the northeast, Nanaga Formation arenite and sand in the west and Bokkeveld, Witteberg and Ecca sandstone and shale in between, and a thin strip of Quaternary sand along the coast. The pure grasslands are limited to the Nanaga and Quaternary sands, whereas thornveld is prominent on the more finely textured soils derived from the Beaufort and Bokkeveld mudstone, arenite and shale. The most important land types include Db, Fa and Ae.

Climate In general the climate is ameliorated by the proximity to the coast. MAP ranges from 450 mm inland in the southwest to 900 mm in the northeast, and decreases slightly from the coast inland. The rainfall is nonseasonal with optima in March and October/November, but summer rainfall increases with distance northeastwards. The coefficient of variation in rainfall is 31% in the southwest inland areas, decreasing to 21% in the extreme northeasterly parts. There is a strong rainfall gradient across this unit, with higher rainfall further northeast, which influences species composition, with more subtropical elements up the coast and more drought-tolerant elements farther west. There is little variation in temperature from season to season and frost occurs on average for only 3 days a year in the inland sites and never at the coast. Mean monthly maximum and minimum temperatures for East London are 32.3°C and 5.3°C for March and July, respectively. See also climate diagram for AT 9 Albany Coastal Belt (Figure 10.4).

Important Taxa Tall Tree: *Erythrina caffra*. Succulent Tree: *Euphorbia triangularis*. Small Trees: *Acacia natalitia* (d), *Brachylaena elliptica*, *Canthium spinosum*, *Cussonia spicata*, *Ficus sur*, *Ochna arborea*, *Sideroxylon inerme*, *Zanthoxylum capense*. Tall Shrubs: *Clausena anisata*, *Clerodendrum glabrum*, *Coddia rudis*, *Croton rivularis*, *Diospyros villosa* var. *parvifolia*, *Grewia occidentalis*, *Gymnosporia heterophylla*, *Hippobromus pauciflorus*, *Mystroxylon aethiopicum*, *Pavetta lanceolata*, *Psydrax obovata*, *Pterocelastrus tricuspidatus*, *Rhus lucida*, *Scutia myrtina*, *Tarchonanthus camphoratus*, *Turraea obtusifolia*. Low Shrubs: *Rhynchosia ciliata* (d), *Carissa bispinosa* subsp. *bispinosa*, *Chaetacanthus setiger*, *Helichrysum asperum* var. *albidulum*, *Pelargonium alchemilloides*, *Phyllanthus maderaspatensis*, *Selago corymbosa*, *Senecio pterophorus*, *Tephrosia capensis* var. *acutifolia*. Semiparasitic Epiphytic Shrub: *Viscum obscurum*. Woody Succulent Climbers: *Crassula pellucida* subsp. *marginalis*, *Sarcostemma viminale*. Woody Climbers: *Asparagus aethiopicus*, *A. racemosus*, *Capparis sepiaria* var. *citrifolia*, *Clematis brachiata*, *Rhoiacarpos capensis*, *Rhoicissus digitata*, *R. tridentata*, *Secamone alpini*, *Tecoma capensis*. Herbaceous Climbers: *Rhynchosia caribaea*, *R. totta, Thunbergia capensis*, *Zehneria*

scabra. Graminoids: *Brachiaria serrata* (d), *Cynodon dactylon* (d), *Dactyloctenium australe* (d), *Digitaria natalensis* (d), *Ehrharta calycina* (d), *Eragrostis capensis* (d), *E. curvula* (d), *E. plana* (d), *Heteropogon contortus* (d), *Panicum deustum* (d), *P. maximum* (d), *Setaria sphacelata* (d), *Sporobolus africanus* (d), *Themeda triandra* (d), *Tristachya leucothrix* (d), *Cymbopogon marginatus*, *Ehrharta erecta*, *Elionurus muticus*, *Melica racemosa*, *Setaria megaphylla*, *Trachypogon spicatus*. Succulent Herb: *Plectranthus verticillatus* (d). Geophytic Herbs: *Cheilanthes hirta*, *Moraea pallida*, *Oxalis smithiana, Sansevieria hyacinthoides*, *Strelitzia reginae*. Herbs: *Chamaecrista mimosoides* (d), *Abutilon sonneratianum*, *Acalypha ecklonii*, *Centella asiatica*, *Commelina africana*, *C. benghalensis*, *Cynoglossum hispidum*, *Eriosema squarrosum*, *Lactuca inermis*, *Lobelia erinus*, *Monsonia emarginata*, *Phyllopodium cuneifolium*, *Senecio burchellii*, *Sonchus dregeanus*.

Endemic Taxa Succulent Shrub: *Bergeranthus concavus*. Succulent Herbs: *Brachystelma franksiae* var. *grandiflorum, Bulbine frutescens* var. nov. *('chalumnensis'* Baijnath ined.), *Faucaria subintegra*, *Haworthia coarctata* var. *tenuis*, *H. cooperi* var. *venusta*, *H. reinwardtii* var. *reinwardtii f. chalumnensis*, *Stapelia praetermissa* var. *luteola*, *S. praetermissa* var. *praetermissa*. Geophytic Herbs: *Bobartia gracilis, Apodolirion amyanum*, *Aspidoglossum flanaganii*, *Drimia chalumnensis*. Low Shrub: *Acmadenia kiwanensis*. Herb: *Monsonia galpinii*.

Conservation Least threatened. Target 19%. Only 1% of this vegetation unit is protected in 20 local-authority and provincial nature reserves as well as in the Greater Addo Elephant National Park (including Alexandria Coast Reserve West) as well as in number of private conservation areas. About 12% of the Albany Coastal Belt has recently been altered by cultivation, 1% by plantation forestry and 4% by urbanisation. According to land-cover data, at least 7% consists of degraded vegetation. It is difficult, however, to determine the proportion of the vegetation that is in a secondary state, since land-cover data do not distinguish between primary and secondary vegetation. Erosion is very low to moderate.

Remarks The seaboard region that contains this unit is a mosaic of a wide variety of structural vegetation types, ranging from grassland to forest. This variation reflects post-disturbance succession gradients as well as natural variation in geology, soil patterns and distribution of water in the landscape. The forests of the region have been mapped as different vegetation units (see Chapter on Forests in this book). Admittedly, this vegetation unit exemplifies a deviation from our mapping philosophy by featuring current-state rather than potential vegetation. We assume that the current vegetation mosaic so typical of the Albany Coastal Belt is a creation of man and the original (pre-settlement) vegetation was dominated by nonseasonal, dense thicket. The area of this unit was prime agricultural land which attracted early settlers who, presumably, cleared the dense thicket cloak for pastures.

References Acocks (1953, 1988), Judd (2001), Vlok & Euston-Brown (2002), Vlok et al. (2003).

AT 10 Great Fish Noorsveld

VT 23 Valley Bushveld (100%) (Acocks 1953). Valley Bushveld (94%) (Moll & Bossi 1984). LR 6 Xeric Succulent Thicket (84%) (Low & Rebelo 1996, 1998). STEP Fish Noorsveld (100%) (Vlok & Euston-Brown 2002).

Distribution Eastern Cape Province: One large patch surrounded mainly by Great Fish Thicket in the valley of the Great Fish River (north of Grahamstown) and spans a broad band from around Pigott's (Carlisle) Bridge in the west to around Committees Drift in the east, as well as unmapped patches in the Ecca Pass and its surroundings. Altitude 100–500 m.

Vegetation & Landscape Features Prevalent on plateaus and mildly sloping flanks of ridges supporting succulent thicket of low to medium height dominated by the local endemic *Euphorbia bothae* (a hybrid crowd) as well as other *Euphorbia* species intermixed with sclerophyllous bush clumps (*Euclea, Grewia, Gymnosporia, Putterlickia, Schotia*), groups of succulent shrubs (*Crassula, Cotyledon, Pelargonium*), patches of rhizomatous herbs (*Sansevieria hyacinthoides, Strelitzia reginae*) and accompanied by species-rich grass flora. *Portulacaria afra* is dominant on rocky outcrops.

Geology & Soil Mostly finely laminated clastic sediments of the Ecca Group (particularly the Fort Brown Formation) supporting skeletal shallow soils (Glenrosa and Mispah). Fc is the overwhelmingly dominant land type, Fb only of minor importance.

Climate Nonseasonal rainfall with optima in March and October/November. MAP ranges from about 360 mm to 500 mm, with the higher rainfall generally in the central parts. The incidence of frost is 3 days per annum, varying little across the range of the unit, except in the extreme eastern part where no frost occurs. Mean monthly maximum and minimum temperatures for Tyefu weather station are 39.6°C and 2.1°C for January and July, respectively. See also climate diagram for AT 10 Great Fish Noorsveld (Figure 10.4).

Important Taxa Succulent Trees: *Aloe africana*, *A. ferox*. Small Trees: *Schotia afra* var. *afra* (d), *Acacia natalitia*, *Boscia albitrunca*,

L. Mucina

Figure 10.13 AT 10 Great Fish Noorsveld: Stand of *Strelitzia reginae* (Strelitziaceae) in Noorsveld near Ecca Pass (north of Grahamstown, Eastern Cape). The low succulent is *Euphorbia x bothae,* an endemic taxon to this vegetation unit.

Cussonia spicata, *Pappea capensis*, *Ptaeroxylon obliquum*. Tall Shrubs: *Azima tetracantha* (d), *Grewia robusta* (d), *Brachylaena ilicifolia*, *Cadaba aphylla*, *Ehretia rigida*, *Euclea undulata*, *Gymnosporia capitata*, *Lantana rugosa*, *Rhigozum obovatum*. Low Shrubs: *Asparagus striatus*, *A. subulatus*, *Ballota africana*, *Becium burchellianum*, *Chrysocoma ciliata*, *Garuleum latifolium*, *Hermannia althaeoides*, *Indigofera sessilifolia*, *Jatropha capensis*, *Leucas capensis*, *Limeum aethiopicum*, *Phyllanthus maderaspatensis*, *Pteronia incana*, *Selago fruticosa*, *Senecio linifolius*, *S. pterophorus*, *Solanum tomentosum*. Succulent Shrubs: *Cotyledon orbiculata* var. *oblonga* (d), *Mestoklema tuberosum* (d), *Portulacaria afra* (d), *Crassula nudicaulis*, *C. tetragona* subsp. *acutifolia*, *Euphorbia mauritanica*, *E. pentagona*, *E. rectirama*, *Kalanchoe rotundifolia*, *Orthopterum waltoniae*, *Pachypodium succulentum*. Semiparasitic Shrub: *Thesium lineatum*. Semiparasitic Epiphytic Shrub: *Viscum rotundifolium*. Woody Succulent Climbers: *Crassula perforata*, *Cyphostemma quinatum*. Woody Climbers: *Asparagus racemosus* (d), *A. multiflorus*, *Rhoicissus digitata*. Graminoids: *Aristida congesta* (d), *Cynodon dactylon* (d), *Cyperus bellus* (d), *Digitaria argyrograpta* (d), *Panicum deustum* (d), *Paspalum distichum* (d), *Sporobolus fimbriatus* (d), *S. nitens* (d), *Tragus koelerioides* (d), *Chloris virgata*, *Cymbopogon pospischilii*, *Cynodon incompletus*, *Ehrharta erecta*, *Eragrostis chloromelas*, *E. curvula*, *E. lehmanniana*, *E. obtusa*, *Karroochloa curva*, *Leptochloa fusca*, *Microchloa caffra*, *Oropetium capense*, *Panicum coloratum*, *P. gilvum*, *P. maximum*, *P. stapfianum*, *Themeda triandra*. Succulent Herb: *Crassula expansa* (d), *C. muscosa*, *Mesembryanthemum aitonis*, *Senecio radicans*. Geophytic Herbs: *Sansevieria hyacinthoides* (d), *Strelitzia reginae* (d), *Bulbine asphodeloides*, *B. narcissifolia*, *Cyrtanthus smithiae*. Herbs: *Aizoon glinoides*, *Amellus strigosus* subsp. *pseudoscabridus*, *Atriplex suberecta*, *Commelina africana*, *Dolichos hastaeformis*, *Lepidium africanum*, *Pharnaceum dichotomum*, *Salvia stenophylla*.

Biogeographically Important Taxon Geophytic Herb: *Drimia acarophylla* (shared with Great Fish Thicket).

Endemic Taxon Succulent Shrub: *Euphorbia* x *bothae* (d).

Conservation Least threatened. Target 19%. Good examples of the Great Fish Noorsveld are conserved in a series of statutory nature reserves around and north of the Ecca Pass. A total of about 3% of the vegetation is in the Great Fish River Complex Nature Reserve, which includes the Andries Vosloo Nature Reserve. An additional 31% is conserved in several large-scale private reserves and game farms, mainly the Kwande Private Game Reserve. Great Fish Noorsveld has been relatively little transformed: only about 3% by cultivation. Erosion is moderate to high. This vegetation type contains the largest wild populations of the famous *Strelitzia reginae*—a flagship plant of South Africa.

References Palmer (1981), Palmer et al. (1988), Vlok & Euston-Brown (2002), Brink & Dold (2003), Vlok et al. (2003).

AT 11 Great Fish Thicket

VT 23 Valley Bushveld (38%), VT 37 False Karroid Broken Veld (30%) (Acocks 1953). LR 52 Eastern Mixed Nama Karoo (26%), LR 6 Xeric Succulent Thicket (19%), LR 16 Eastern Thorn Bushveld (17%) (Low & Rebelo 1996, 1998). STEP Fish Spekboom Thicket (42%), STEP Hartebeest Karroid Thicket (24%) (Vlok & Euston-Brown 2002).

Distribution Eastern Cape Province: Mainly in the lower Great Fish River and Keiskamma River Valleys (including the smaller intervening river valleys nearer the coast) extending up the Great Fish River Valley northwards to Cookhouse and into the southernmost part of the Cradock District. Extending up the Keiskamma River Valley as far as its confluence with the Tyume River. Also includes the lower reaches of the Koonap River and part of its upper reaches immediately north of Adelaide, as well as parts of the Kat River and Little Fish River Valleys. Altitude 0–1 000 m.

Vegetation & Landscape Features Steep slopes of deeply dissected rivers supporting short, medium and tall thicket types (Palmer 1981, Palmer et al. 1988, Evans et al. 1997), where both the woody trees and shrubs and the succulent component are well developed, with many spinescent shrubs. *Portulacaria afra* is locally dominant, decreasing in relative abundance and is replaced by *Euphorbia bothae* with increasing aridity. With increasing moisture status on southern aspects and in the riparian zone, *P. afra* is replaced by woody elements and tall emergent *Euphorbia tetragona* and *E. triangularis*. There is distinct clumping of the vegetation, which is linked to zoogenic mounds, formed principally by termites (*Microhodotermes viator*), earthworms (*Microchaetus*), mole rats (*Cryptomus hottentotus*) and aardvarks (*Orycteropus afer*)—these islands of concentrated nutrients and moisture have richer, deep soils and are often occupied by long-lived woody shrubs and trees such as *Pappea capensis* and *Boscia oleoides* and provide deep soils for endemic geophytes. The closed canopy of the *Portulacaria afra*-dominated thicket is another distinctive feature of parts of the Great Fish Thicket. There is high heterogeneity within this vegetation unit, which has been divided into nine distinct subtypes (Vlok & Euston-Brown 2002).

Geology & Soils Mostly on shallow (<1 m) clay soils (Glenrosa and Mispah) derived from the Adelaide and Estcourt Formations (Beaufort Group, Karoo Supergroup) mudstone and arenite. Half of the area falls within the Fc land type, with Fb the only other one of some importance.

Climate Nonseasonal rainfall with slight optima in March and October/November. MAP ranges from about 300 mm in the western inland areas to 600 mm in the eastern coastal areas. The coefficient of variation in MAP is 32%, but varies from 29% at the coast to 36% inland. The mean daily maximum temperatures for January are 26°C at the coast and 30°C inland and the mean daily minimum temperatures for July are 0°C inland and 9°C at the coast. The incidence of frost is 3 days, but ranging widely from 0 days at the coast to more than 60 days in the upper reaches of the river valley. See also climate diagram for AT 11 Great Fish Thicket (Figure 10.4).

Important Taxa Succulent Trees: *Euphorbia triangularis* (d), *Aloe ferox*, *Euphorbia tetragona*. Small Trees: *Pappea capensis* (d), *Acacia natalitia*, *Boscia albitrunca*, *Brachylaena ilicifolia*, *Cussonia spicata*, *Ozoroa mucronata*, *Ptaeroxylon obliquum*, *Schotia afra* var. *afra*, *Zanthoxylum capense*. Tall Shrubs: *Euclea undulata* (d), *Allophylus decipiens*, *Azima tetracantha*, *Carissa bispinosa* subsp. *bispinosa*, *Coddia rudis*, *Diospyros scabrida* var. *cordata*, *Ehretia rigida*, *Flueggea verrucosa*, *Grewia occidentalis*, *G. robusta*, *Gymnosporia capitata*, *G. heterophylla*, *Hippobromus pauciflorus*, *Mystroxylon aethiopicum*, *Olea europaea* subsp. *africana*, *Putterlickia pyracantha*, *Rhus incisa*, *R. refracta*, *Scolopia zeyheri*, *Scutia myrtina*. Low Shrubs: *Asparagus striatus* (d), *Chaetacanthus setiger* (d), *Chrysocoma ciliata* (d), *Asparagus subulatus*, *Felicia muricata*, *Hermannia althaeoides*, *Indigofera sessilifolia*, *Leucas capensis*, *Limeum aethiopicum*, *Lycium cinereum*, *Phyllanthus maderaspatensis*, *Selago fruticosa*. Succulent Shrubs: *Crassula cordata* (d), *C. ovata* (d), *Portulacaria afra* (d), *Aloe tenuior*, *Delosperma ecklonis*, *Kalanchoe rotundifolia*, *Mestoklema tuberosum*, *Tetradenia barberae*. Semiparasitic Epiphytic Shrub: *Viscum rotundifolium*. Woody Succulent Climbers: *Crassula perforata*,

A.L. Kamineth

Figure 10.14 AT 11 Great Fish Thicket: Valley slopes clad in dense succulent thicket in the Sam Knott Nature Reserve (near Grahamstown, Eastern Cape).

Cyphostemma quinatum, *Pelargonium peltatum*, *Sarcostemma viminale*. Woody Climbers: *Asparagus multiflorus*, *A. racemosus*, *Capparis sepiaria* var. *citrifolia*, *Jasminum angulare*, *Plumbago auriculata*, *Rhoicissus digitata*. Graminoids: *Aristida congesta* (d), *Cynodon incompletus* (d), *Digitaria eriantha* (d), *Ehrharta erecta* (d), *Eragrostis obtusa* (d), *Panicum deustum* (d), *P. maximum* (d), *P. stapfianum* (d), *Setaria sphacelata* (d), *Sporobolus fimbriatus* (d), *S. nitens* (d), *Themeda triandra* (d), *Tragus berteronianus* (d), *T. koelerioides* (d), *Cymbopogon pospischilii*, *Eragrostis chloromelas*, *E. curvula*, *Eustachys paspaloides*. Herbs: *Cyanotis speciosa* (d), *Hypoestes aristata* (d), *Salvia scabra* (d), *Abutilon sonneratianum*, *Aizoon glinoides*, *Hibiscus pusillus*, *Lepidium africanum*, *Sida ternata*. Succulent Herbs: *Crassula expansa* (d), *Senecio radicans*. Geophytic Herb: *Sansevieria hyacinthoides* (d).

Endemic Taxa Succulent Shrub: *Euphorbia cumulata*. Low Shrub: *Euryops gracilipes*. Succulent Herbs: *Haworthia angustifolia* var. *paucifolia*, *H. cummingii*, *H. cymbiformis* var. *incurvula*, *H. cymbiformis* var. *ramosa*. Herb: *Zaluzianskya vallispiscis*.

Conservation Least threatened. Target 19%. A total of 6% of this vegetation unit is protected in seven statutory reserves, especially in the Great Fish River Complex Nature Reserve and 4.5% in addition in at least nine private conservation areas. Great Fish Thicket has not been radically altered, only 3% by cultivation and 1% by urbanisation. Erosion is very variable, from high to low.

Remarks This is the easternmost vegetation unit assigned to the Albany Thicket Biome, except for Buffels Thicket that only occurs near the coast. The climate in these deep, wide river valleys is hotter and dryer than the surrounding countryside and the area covered by this vegetation unit may constitute an effective physical barrier to species migration in an east-west direction through this region. The vegetation unit also marks the transition between more concentrated summer rainfall and nonseasonal rainfall. The northeastern side of this vegetation unit is marked by the east-west-running Amathole-Winterberg mountain ranges (with its band of Eastern Cape Escarpment Thicket), further enhancing the barrier nature of this area.

References Acocks (1953, 1988), Palmer (1981), Cowling (1984), Everard (1987), Palmer et al. (1988), La Cock (1992), Stuart-Hill (1992), Stuart-Hill & Aucamp (1993), Evans et al. (1997), Lloyd et al. (2002), Vlok & Euston-Brown (2002), Vlok et al. (2003), Kamineth (2004).

AT 12 Buffels Thicket

VT 1 Coastal Forest and Thornveld (40%), VT 23 Valley Bushveld (39%) (Acocks 1953). LR 48 Coastal Grassland (31%), LR 5 Valley Thicket (30%) (Low & Rebelo 1996). STEP Mountcoke Grassland Thicket (45%), STEP Buffels Thicket (32%) (Vlok & Euston-Brown 2002).

Distribution Eastern Cape Province: In river valleys centred around East London, including the Tyolomnqa River, Buffalo River, Nahoon River, Gqunube River, Kwelera River and stretching between 40 and 50 km inland (including some areas around King William's Town and Komga), and a small area in the Great Kei River Valley between about 10 and 20 km from the coast. It also occurs in the valley bottom in Keiskammahoek north of Dimbaza. Altitude 0–700 m.

Vegetation & Landscape Features Steep slopes of river valleys in highly dissected hills and moderately undulating plains, where short, dense and tangled thicket stands reach up to 10 m. The dense thicket grades into more open, shorter thornveld at the edges of the valley slopes.

Geology & Soils Mudstones and sandstones derived from the Beaufort Group of the Karoo Supergroup as well as Jurassic Dolerite Suite intrusions. The shallow soils (Glenrosa and Mispah) derived from these rocks are fine-grained, nutrient-poor silts, but the presence of forests leads to the development of humus-rich, deep soils. Half of the area is classified as Fa land type, while Fb and Bd are of subordinate importance.

Climate Mild climate with few extremes, ameliorated by the close proximity of the Indian Ocean. Rainfall is 500–840 mm per year, and has a coefficient of variation of 22–29%, the higher coefficients occurring in the more inland, less steep sites. The rainfall occurs in spring and early to midsummer, but typically of the Eastern Cape it may occur at any time of the year. Mean monthly maximum and minimum temperatures for East London are 32.3°C and 5.3°C for March and July, respectively, with very little chance of frost. See also climate diagram for AT 12 Buffels Thicket (Figure 10.4).

Important Taxa Succulent Trees: *Euphorbia triangularis* (d), *Aloe ferox*, *Euphorbia grandidens*. Small Trees: *Acacia natalitia*, *Apodytes dimidiata*, *Brachylaena ilicifolia*, *Calodendrum capense*, *Canthium ciliatum*, *C. mundianum*, *Cussonia spicata*, *C. thyrsiflora*, *Dombeya tiliacea*, *Elaeodendron croceum*, *Eugenia zeyheri*, *Harpephyllum caffrum*, *Heteromorpha arborescens*, *Ochna arborea*, *Pappea capensis*, *Ptaeroxylon obliquum*, *Schotia afra* var. *afra*, *S. latifolia*, *Sideroxylon inerme*, *Trimeria trinervis*, *Vepris lanceolata*, *Zanthoxylum capense*, *Ziziphus mucronata*. Tall Shrubs: *Allophylus decipiens* (d), *Azima tetracantha* (d), *Scutia myrtina* (d), *Suregada africana* (d), *Acalypha glabrata*, *Acokanthera oppositifolia*, *Allophylus melanocarpus*, *Buddleja dysophylla*, *Carissa bispinosa* subsp. *bispinosa*, *Chaetacme aristata*, *Chrysanthemoides monilifera*, *Clerodendrum glabrum*, *Coddia rudis*, *Croton rivularis*, *Diospyros scabrida* var. *cordata*, *D. simii*, *D. villosa* var. *parvifolia*, *Ehretia rigida*, *Euclea natalensis*, *E. undulata*, *Grewia occidentalis*, *Gymnosporia buxifolia*, *G. heterophylla*, *G. nemorosa*, *Hippobromus pauciflorus*, *Maytenus acuminata*, *Mystroxylon aethiopicum*, *Olea*

europaea subsp. *africana*, *Pavetta lanceolata*, *Putterlickia pyracantha*, *P. verrucosa*, *Rhus gueinzii*, *R. lucida*, *Scolopia zeyheri*. Low Shrubs: *Pavonia praemorsa* (d), *Senecio pterophorus* (d), *Euphorbia kraussiana*, *Lauridia tetragona*, *Lippia javanica*, *Lycium cinereum*, *Rubus rigidus*, *Solanum rigescens*. Succulent Shrubs: *Aptenia cordifolia* (d), *Exomis microphylla* var. *axyrioides*, *Senecio oxyodontus*. Woody Succulent Climbers: *Cyphostemma quinatum*, *Sarcostemma viminale*. Woody Climbers: *Rhoicissus digitata* (d), *Asparagus aethiopicus*, *A. racemosus*, *Capparis sepiaria* var. *citrifolia*, *Dalbergia obovata*, *Jasminum angulare*, *Plumbago auriculata*, *Rhoicissus tomentosa*, *R. tridentata*, *Secamone alpini*, *Tecoma capensis*, *Uvaria caffra*. Graminoids: *Cynodon dactylon* (d), *Cyperus albostriatus* (d), *C. textilis* (d), *Digitaria argyrograpta* (d), *D. natalensis* (d), *Ehrharta erecta* (d), *Microchloa caffra* (d), *Panicum deustum* (d), *P. maximum* (d), *Schoenoxiphium sparteum* (d), *Setaria megaphylla* (d), *S. sphacelata* (d), *Paspalum dilatatum*. Herbaceous Climbers: *Senecio deltoideus* (d), *Coccinia quinqueloba*, *Cynanchum ellipticum*, *Helinus integrifolius*. Succulent Herbs: *Sansevieria hyacinthoides* (d), *Plectranthus grandidentatus*. Geophytic Herbs: *Moraea pallida*, *Ornithogalum longibracteatum*, *Cheilanthes hirta*. Herbs: *Commelina benghalensis* (d), *Conyza scabrida* (d), *Galopina circaeoides* (d), *Hypoestes aristata* (d), *Abutilon sonneratianum*, *Sida ternata*.

Endemic Taxon Woody Succulent Climber: *Ceropegia radicans* subsp. *smithii*.

Conservation Vulnerable. Target 19%. About 1% is protected in statutory reserves (Umtiza, Bridle Drift, Fort Pato, Nahoon, Bluebend, King William's Town Nature Reserves) and in addition 0.7% in private nature conservation areas. Transformation 21%, mainly by cultivation, urban and built up areas, and plantations. At least 15% consists of vegetation in a degraded state. Erosion very low to moderate.

References Acocks (1953, 1988), Low & Rebelo (1996), Vlok & Euston-Brown (2002), Vlok et al. (2003), Kamineth (2004).

AT 13 Eastern Cape Escarpment Thicket

VT 21 False Thornveld of Eastern Province (34%), VT 23 Valley Bushveld (20%) (Acocks 1953). LR 52 Eastern Mixed Nama Karoo (26%), LR 15 Subarid Thorn Bushveld (23%), LR 5 Valley Thicket (20%) (Low & Rebelo 1996, 1998). STEP Escarpment Thicket (74%) (Vlok & Euston-Brown 2002).

Distribution Eastern Cape Province: At the southern foot of the steep escarpment slopes of the Amathole, Winterberg and Swaershoek Mountains from the western flank of the Keiskammahoek District to just west of Somerset East as well as on the foothills of mountains and on hills in the mountainous regions centred within a radius of 25–35 km south and west of Cradock. Altitude 450–1 250 m.

Vegetation & Landscape Features Steeply sloping escarpment and mountain slopes, hills and lowlands of the region where it forms a medium high, semi-open to closed thicket dominated by *Olea europaea* subsp. *africana* and *Acacia natalitia* 3–7 m tall, grading into thornveld lower down and often into escarpment forest higher up the slopes.

Geology & Soils Mudstones and arenite of the Adelaide Subgroup of the Karoo Supergroup as well as Jurassic dolerite intrusions. The soils derived from these rocks are fine-grained, nutrient-poor silts or more nutrient-rich red clays. Soils are often shallow, on moderate to steep slopes and the surface rock cover is high. The major land types are Fc as well as Ib and Fb.

Climate Nonseasonal rainfall with optima in March and November, with February and March being the maximum months. MAP ranges from about 400–700 mm per annum on the southern side of the escarpment and from 310–400 mm per annum on the northern side around Cradock, increasing with elevation. The coefficient of variation in MAP is 25–35%, increasing with decreasing amounts of rainfall. The incidence of frost is 16 days, but ranging widely from fewer than 5 days to more than 35 days of frost per year, the areas with more frost occurring higher up the escarpment slopes where snow may occur in winter. Mean monthly maximum and minimum temperatures for Somerset East are 38.6°C and –1.0°C for January and July, respectively. See also climate diagram for AT 13 Eastern Cape Escarpment Thicket (Figure 10.4).

Important Taxa Succulent Trees: *Aloe ferox*, *Euphorbia tetragona*. Small Trees: *Acacia karroo* (d), *Cussonia spicata*. Tall Shrubs: *Olea europaea* subsp. *africana* (d), *Scutia myrtina* (d), *Buddleja auriculata*, *Euclea crispa*, *E. undulata*, *Grewia occidentalis*, *Gymnosporia heterophylla*, *Hippobromus pauciflorus*, *Leucosidea sericea*, *Myrsine africana*, *Rhus dentata*, *R. lucida*, *R. tomentosa*, *Scolopia zeyheri*. Low Shrubs: *Anthospermum rigidum* subsp. *pumilum*, *Argyrolobium collinum*, *Asparagus striatus*, *Chaetacanthus setiger*, *Felicia filifolia*, *F. muricata*, *Hermannia althaeoides*, *Lantana rugosa*, *Pelargonium alchemilloides*, *Phyllanthus maderaspatensis*, *Polygala fruticosa*, *Selago corymbosa*, *Solanum rigescens*. Succulent Shrubs: *Bergeranthus artus*, *Crassula obovata*. Semiparasitic Epiphytic Shrub: *Viscum rotundifolium*. Woody Climbers: *Asparagus aethiopicus*, *Plumbago auriculata*. Herbaceous Climber: *Senecio deltoideus* (d). Graminoids: *Aristida congesta* (d), *Cynodon incompletus* (d), *Ehrharta calycina* (d), *E. erecta* (d), *Eragrostis chloromelas* (d), *E. curvula* (d), *Panicum maximum* (d), *Sporobolus fimbriatus* (d), *Tragus berteronianus* (d), *Aristida diffusa*, *A. junciformis* subsp. *junciformis*, *Cymbopogon marginatus*, *C. pospischilii*, *Cynodon dactylon*, *Eragrostis obtusa*, *Heteropogon contortus*, *Melica decumbens*, *Panicum deustum*, *P. stapfianum*, *Sporobolus africanus*. Succulent Herbs: *Stapelia glabricaulis*. Geophytic Herbs: *Drimia uniflora* (d), *Bulbine asphodeloides*, *B. narcissifolia*, *Drimia intricata*. Herbs: *Cyanotis speciosa* (d), *Amaranthus praetermissus*, *Blepharis integrifolia* var. *clarkei*, *Commelina africana*, *Dianthus caespitosus*, *Gerbera piloselloides*, *Hibiscus aethiopicus*, *H. pusillus*, *Hypoestes aristata*, *Senecio retrorsus*, *Sida ternata*.

Conservation Target 19%. Eastern Cape Escarpment Thicket has been permanently altered, with 3% through cultivation and 1% through urbanisation. A total of 5% of this vegetation unit is statutorily conserved in local-authority nature reserves (Bosberg), provincial nature reserves (primarily the Mpofu Game Reserve and Bush Nek Outspan) and in the Mountain Zebra National Park. A further about 2% is protected in private conservation areas. Erosion is very variable, from very low to high.

Remarks Close floristic relationship and similar structure to AT 14 Camdebo Escarpment Thicket to the west and Gs 17 Tarkastad Montane Shrubland to the north, and also grades into the more mesic Buffels Thicket to the east.

References Acocks (1953, 1988), Vlok & Euston-Brown (2002), Vlok et al. (2003), Brown & Bezuidenhout (2005).

AT 14 Camdebo Escarpment Thicket

VT 37 False Karroid Broken Veld (41%), VT 25 Succulent Mountain Scrub (Spekboomveld) (33%) (Acocks 1953). LR 54 Central Lower Nama Karoo (41%), LR 5 Valley Thicket (40%) (Low & Rebelo 1996, 1998). STEP Escarpment Spekboomveld (41%), STEP Escarpment Valley Thicket (22%) (Vlok & Euston-Brown 2002).

L. Mucina

Figure 10.15 AT 14 Camdebo Escarpment Thicket: *Crassula arborescens* (Crassulaceae) in succulent thicket in the Rooiberg east of Aberdeen (Eastern Cape).

Distribution Eastern Cape Province: South-sloping face of the Great Escarpment, forming an arc from Bruintjieshoogte in the east via the Coetzeeberg Mountains and Graaff-Reinet (including Spandaukop and the isolated Rooiberg) to Kamdebooberg and Aberdeen in the west. Altitude varies from 570–1 600 m, with most of the area between 700–1 200 m.

Vegetation & Landscape Features Occurs on the rugged, broken and steeply sloping escarpment and mountain slopes of the region where it forms a 2–3 m tall, largely succulent thicket of *Portulacaria afra*-dominated clumps. Heavy browsing by goats reduces or eliminates *P. afra* and low trees (*Pappea capensis* and *Boscia oleoides*) remain.

Geology & Soil Sandstone and mudstone of the Permian Adelaide Subgroup (Beaufort Group), interrupted in places by dykes of Jurassic Karoo dolerites. Shallow skeletal soils (varying in depth from 20–30 cm) of Mispah form, with organically rich orthic A-horizon, moderately acidic. Land types are Ib and Fc on shallow substrates and Da duplex soils on dolerite dykes.

Climate Nonseasonal rainfall with optima in March and November and with February and March being the maximum months. MAP ranges from about 270–550 mm, increasing with elevation. The incidence of frost is 25 days, but ranging widely from fewer than 8 days to more than 40 days of frost per year, the areas with more frost occurring higher up the escarpment slopes where snow may occur in winter. Mean monthly maximum and minimum temperatures for Graaff-Reinet are 38.6°C and –0.3°C for January and July, respectively. See also climate diagram for AT 14 Camdebo Escarpment Thicket (Figure 10.4).

Important Taxa Succulent Tree: *Aloe ferox*. Small Trees: *Acacia karroo* (d), *Pappea capensis* (d), *Boscia albitrunca*, *B. oleoides*, *Cussonia paniculata*, *C. spicata*, *Maytenus undata*, *Schotia afra* var. *afra*. Tall Shrubs: *Euclea undulata* (d), *Gymnosporia polyacantha* (d), *Buddleja glomerata*, *Cadaba aphylla*, *Carissa bispinosa* subsp. *bispinosa*, *Diospyros lycioides*, *D. pallens*, *Ehretia rigida*, *Grewia robusta*, *Gymnosporia capitata*, *G. heterophylla, Olea europaea* subsp. *africana*, *Rhus longispina*, *R. lucida*. Low Shrubs: *Blepharis mitrata* (d), *Chrysocoma ciliata* (d), *Lycium schizocalyx* (d), *Pentzia incana* (d), *Rhigozum obovatum* (d), *Aptosimum elongatum*, *Asparagus burchellii*, *A. mucronatus*, *A. striatus*, *A. suaveolens*, *Blepharis capensis*, *B. villosa*, *Eriocephalus ericoides*, *Felicia filifolia*, *F. muricata*, *Garuleum latifolium*, *Helichrysum dregeanum*, *H. zeyheri*, *Hermannia filifolia*, *Indigofera sessilifolia*, *Lantana rugosa*, *Lycium oxycarpum*, *Macledium spinosum*, *Monechma spartioides*, *Pegolettia retrofracta*, *Peliostomum origanoides*, *Rosenia humilis*, *Solanum capense*, *Sutera halimifolia*. Succulent Shrubs: *Portulacaria afra* (d), *Crassula ovata*, *C. rogersii*, *Euphorbia mauritanica*, *E. obesa*, *Kleinia longiflora*, *Mestoklema tuberosum*, *Pachypodium succulentum*, *Trichodiadema barbatum*. Semiparasitic Epiphytic Shrub: *Viscum rotundifolium*. Woody Succulent Climber: *Sarcostemma viminale*. Woody Climbers: *Asparagus racemosus*, *Cissampelos capensis*, *Dioscorea elephantipes*, *Rhoicissus digitata*, *R. tridentata*. Graminoids: *Aristida adscensionis* (d), *A. congesta* (d), *Cenchrus ciliaris* (d), *Digitaria eriantha* (d), *Enneapogon desvauxii* (d), *Eragrostis lehmanniana* (d), *E. obtusa* (d), *Heteropogon contortus* (d), *Aristida diffusa*, *Cynodon incompletus*, *Enneapogon scoparius*, *Eragrostis chloromelas*, *E. curvula*, *Eustachys paspaloides*, *Fingerhuthia africana*, *Panicum maximum*, *Sporobolus fimbriatus*, *Themeda triandra*, *Tragus berteronianus*, *T. koelerioides*. Succulent Herb: *Mesembryanthemum aitonis*. Geophytic Herbs: *Boophone disticha*, *Drimia anomala*, *D. intricata, Moraea polystachya*. Herbs: *Abutilon sonneratianum*, *Aizoon glinoides*, *A. rigidum*, *Asplenium cordatum*, *Cheilanthes deltoidea*, *Gazania krebsiana*, *Hermannia coccocarpa*, *H. comosa*, *H. pulverata*, *Hibiscus pusillus*, *Lepidium africanum*, *Pollichia campestris*, *Troglophyton capillaceum*.

Endemic Taxa Succulent Shrubs: *Astroloba corrugata*, *Bergeranthus* sp. nov. (*'nanus'* A.P. Dold ined.), *Delosperma karrooicum*, *Trichodiadema olivaceum*. Succulent Herb: *Haworthia marumiana* var. *batesiana, Huernia kennedyana*. Geophytic Herbs: *Apodolirion bolusii*, *Dierama grandiflorum.*

Conservation Least threatened. Target 19%. About 5% of this vegetation unit is statutorily protected in the Karoo Nature Reserve and a further 15% in private conservation areas (Samara Private Game Reserve, Asanta Sana Game Reserve, Rupert Game Farm, Buchanon Game Farm, Hoeksfontein Game Farm and Glen Harry Game Reserve). Camdebo Escarpment Thicket has been transformed by only about 1%, through cultivation, but this vegetation has been subjected to degradation through grazing by domestic goats in many places. It is likely that it extended further down the slopes in recent history. Clear fence-line contrasts can be recognised both by satellite imagery and in the field (Lloyd et al. 2002). Erosion is moderate to high.

Remarks The dominance of *Portulacaria afra* is the main link of this unit with the Albany Thicket Biome, as earlier classified (Palmer 1988, 1991a, b). The overall floristic composition suggests rather that this is a marginal Nama-Karoo unit whose thicket structure can be ascribed to special regional habitat conditions, in particular geomorphology and associated microclimate. *P. afra* is a facultative C_3/CAM plant, and its distribution may be linked to CAM being activated following the extreme daily variation in temperature and moisture (Guralnick & Ting 1987) as often experienced on these south-facing slopes. The

distribution of *P. afra*, an important indicator of this thicket, has been modelled using a correlative modelling approach (Robertson & Palmer 2002).

References Acocks (1953, 1988), Palmer (1988, 1989, 1991a, b), Lloyd et al. (2002), Robertson & Palmer (2002), Vlok & Euston-Brown (2002), Vlok et al. (2003).

9. Credits

The Albany Thicket region was mapped using original sources, including contributions of D.B. Hoare (eastern and western parts) and A.R. Palmer (portion of western part); much of the latter was replaced by a detailed unpublished STEP map (Vlok & Euston-Brown 2002). The STEP source (counting more than 100 mapping units) was simplified by M.C. Rutherford and L. Mucina (for the main key see Table 10.1) and many of the more marginal (edge) STEP units were reconciled with other sources. The delimitation of the AT units was also influenced by the delimitation of AZa 6, Gs 18, Gs 16, SVs 6 and SVs 7 (all D.B. Hoare) as well as by placement of the forest patches (so-called Forest Biome forest map; see also Credits in the chapter on Forests). A.P. Dold contributed considerably to the species lists, Albany endemic species in particular. A.R. Palmer contributed to descriptions of units AT 2, 3, 11 and 14. D.B. Hoare contributed to the text of all mapping units except for AT 1. L. Mucina wrote AT 1 and contributed to the text of all other AT units. R.G. Lechmere-Oertel contributed to the text of AT 4 and 6; J.H.J. Vlok and D.I.W. Euston-Brown contributed to the text (list of species in particular) of AT 2 and 3.

The introductory text is the result of a joint effort by (in order of the volume of the contribution) D.B. Hoare (all major sections), A.R. Palmer (Sections 1, 2 and 3), R.G. Lechmere-Oertel (Sections 5 and 6), L. Mucina (sections 4.3 and 7) and Ş.M. Procheş (Section 4.1). The section 3.2 of the introductory text was shaped by A.R. Palmer and R.A. Ward. M.C. Rutherford considerably improved section 3.3. L.W. Powrie and M.C. Rutherford provided physico-geographical information extracted from various GIS sources for the descriptions and constructed the climate diagrams. The references were compiled and collated by L. Mucina. M. Rouget, and others within the Directorate of Biodiversity Programmes, Policy & Planning of SANBI, provided quantitative information for each vegetation unit on conservation status and targets, areas currently conserved and areas transformed.

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Indian Ocean Coastal Belt 11

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List of Vegetation Units

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Figure 11.1 Black Rock north of Sodwana Bay on the Maputaland coast (KwaZulu-Natal) with coastal thicket, subtropical dune forest and fragments of coastal grassland.

W.S. Matthews

1. Introduction

1.1 Position and Landscape Complexity

The region covers the seaboard in two provinces of South Africa—KwaZulu-Natal and the northern half of the Eastern Cape (in the latter part also known as the Wild Coast). This coastal belt in its subtropical facies extends also beyond the national borders into Mozambique as far as the Limpopo River mouth. It continues in strongly tropical facies further northwards into Tanzania, Kenya and southern Somalia (for approximate delimitation, consult Moll & White 1978: Figures 1 and 2). In South Africa it has been known as Coastal Belt (Bews 1920) or as Indian Ocean Coastal Belt (Moll & White 1978). It is the region, both for a biologist and a layman, where South Africa feels the breath of the Tropics the most.

The Indian Ocean Coastal Belt (IOCB) occurs as an almost 800 km long coastal strip between the South African border with Mozambique as far south as the mouth of the Great Kei River (near East London). It spans altitudes from 0–450 m (and higher up to 600 m in the Pondoland-Ugu Sandstone Coastal Sourveld). The landscapes of the IOCB are flat (Maputaland) or characterised by alternating rolling hills and deeply incised valleys (coastal stretch between Richards Bay and Port Edward in KwaZulu-Natal and then more markedly further south to Port St Johns as far as the Great Kei River mouth). Elevated plateaus and deep gorges are characteristic of the Pondoland coast and other regions with underlying sandstone geology. The belt is about 35 km wide at some places in the north (somewhat wider in the valley of the Thukela River), narrowing irregularly southwards to <20 km in parts of Pondoland to <10 km in several parts of the Wild Coast.

The region is very densely populated, with towns such as KwaNgwanase (Manguzi), St Lucia, Mtubatuba, KwaMbonami, Empangeni, Richards Bay, Stanger, Tongaat, Durban Metropolitan Area (Ethekwini), Umkomaas, Port Shepstone, Margate and Port Edward (all KwaZulu-Natal). Further south, in the Eastern Cape, densely populated rural areas are also found, for example in the Xhora District. Much of the KwaZulu-Natal coast (roughly between Stanger and Port Edward) has been turned into a 'South African Riviera'—an almost continuous chain of holiday settlements frequented by millions of tourists every year.

1.2 Biome Identity

Bews (1920: 383), in his classical paper on *The plant ecology of the coast belt of Natal* established that

'... both from the purely ecological and from the floristic standpoints... there are good reasons why the coast belt of Natal should be considered as part of a distinct subtropical region...'.

Later, some researchers would honour this proposition and would recognise the peculiarity of the KwaZulu-Natal (and to an extent also the Wild Coast) immediate seaboards as deserving special status in both ecological (Moll & White 1978; to an extent also Huntley 1984) and biogeographical (Van Wyk & Smith 2001, Heijnis 2004, Kirkwood 2004) terms. The overwhelmingly large extent of transformation of the coastal belt outside the existing strips and patches of embedded forest represents significant loss of evidence of its prior condition. This has led to a diversity of opinions on the broad-level classification of the vegetation of this coastal belt or its components (see Rutherford & Westfall 1986: Table 1 and Figure 4). Although the present work broadly follows Bews (1920) and Moll & White (1978) who assume a dominant forest cover interrupted by edaphically or hydrologically controlled areas of grassland, some others have assumed that at least a significant part of the belt had been an open to dense savanna vegetation, interspersed with many areas of forest and grassland. For example, Huntley (1984) mapped most of the IOCB as his Moist Savanna Biome type in which was embedded smaller but significant areas of his Lowland Forest unit. Rutherford & Westfall (1986) mapped the IOCB as part of their Savanna Biome explicitly on nonfloristic (only structural and climatic) criteria and followed a defined criterion at biome scale level which precluded the mapping of the small or narrow 'lowland forests'. They showed the rainfall seasonality of the IOCB as essentially summer rainfall tending towards even year rainfall near the northern coast. Despite the overriding floristic affinities of forest floras within the IOCB with the African East Coast to the north, the IOCB (the Pondoland-Ugu Sandstone Coastal Sourveld aside) also has some floristic links with savannas toward the northwest interior. Examples of elements straddling both Savanna and IOCB biomes include *Acacia ataxacantha*, *A. caffra*, *A. nilotica*, *A. robusta*, *Combretum molle*, *Erythrina lysistemon*, *Gardenia volkensii*, *Gymnosporia maranguensis*, *Heteropyxis natalensis*, *Ozoroa paniculosa*, *Sclerocarya birrea*, *Turraea obtusifolia* and *Vangueria infausta*. Acocks (1953) supported the notion that the whole IOCB (except the Pondoland Coastal Plateau Sourveld) 'was naturally some form of forest', but acknowledged that the 'veld today is a more or less open thornveld with numerous and extensive patches of forest'.

We argue that the reasons for considering the IOCB a biome in its own right lie in the combination of vegetation structure and combination of climatic characters which are different from the Savanna Biome. The 'tropical appearance of vegetation' (to cite the words of Bews 1920) is a result of a mixture of growth forms such as trees, lianas and epiphytes that dominate the zonal (forest) vegetation of the region, while grasses play only a subordinate role in the zonal vegetation itself. Grasses are, naturally, the structure-shaping growth form in azonal (or intrazonal) vegetation types such as hygrophilic grasslands and shallow-soil sourvelds, also found within IOCB. The presence of these azonal grasslands as well as extensive secondary grasslands led Low & Rebelo (1996, 1998) to classify a large portion of the IOCB as part of the Grassland Biome. The absence of an entirely rain-free dry period (so typically characterising the winter months in the Savanna Biome) and implied increased probability of winter rainfall is another feature distinguishing the IOCB from the Savanna. Although the rainfall of the IOCB is clearly higher in summer than in winter (Figure 1), along the Maputaland coast the winter half-year rainfall makes up as much as 40% of the total yearly precipitation. The overall high air-moisture saturation throughout the year gives the climate of the IOCB its strikingly tropical character, especially in summer.

Burgess et al. (2004) classify this region as part of the global 'Tropical Broadleaved Moist Forest' biome—a concept still much too broad as it would encompass not only the most (sub)tropical forests of the Indian Ocean seaboards (spanning East London and southern Somalia), but also afrotropical rainforests of Central and West Africa.

The biogeographical peculiarity of the IOCB (links to inland tropical regions of Central Africa) and regional concentration of endemic species, initiated an evolution of ideas spanning nearly 100 years (from Marloth 1907 to Van Wyk & Smith 2001). Marloth (1907) suggested 'South Eastern Coast Belt', which would incorporate not only the immediate coastal rims of the present KwaZulu-Natal and Transkei coast of the Eastern Cape, but also the deep hinterland. The 'Coast Belt' of Bews (1920) is a more conservative concept. In fact its extent is very close to

the mapped extent of the IOCB in this chapter. Acocks's (1953; see Acocks Map No. 4 in Acocks 1988) 'Forest and Scrubforest' basically copies the extent of the IOCB as it is depicted in our map. Acocks (1988) recognises the identity of the Coastal Belt in his Veld Type 1 called 'Coastal Forest and Thornveld'—a unit reaching beyond East London westwards as far as Keiskamma and incorporating most of the Maputaland coastal plains. The combination of Low & Rebelo's (1996, 1998) Vegetation Type 23 (Coastal Bushveld/Grassland, largely corresponding to the Acocks's Veld Type 1) and Vegetation Type 48 Coastal Grassland (incorporating the Acocks's Veld Type 3: Pondoland Coastal Plateau Sourveld) roughly corresponds to the IOCB as featured in this chapter. To date, Camp (1999a, b) has undertaken the most detailed climatic, geological and pedological delimitation of the Coastal Belt and classified it as his BRG 1 Moist Coast Forest, Thorn and Palm Veld. We follow (within the borders of the KwaZulu-Natal Province) this delimitation.

The World Wildlife Fund recognises five 'ecoregions' (Goldberg & Frank 2004, Heijnis 2004, Kirkwood 2004, Schipper & Burgess 2004a, b) within so-called 'Tropical and Subtropical Moist Broadleaf Forests' which straddle the Indian Ocean seaboards from the Jubba River in southern Somalia as far south as Port Elizabeth in South Africa. The southern part of the WWF ecoregion Maputaland Coastal Forest Mosaic (Kirkwood 2004) and KwaZulu-Natal-Cape Coastal Forest Mosaic (Heijnis 2004) overlap with the IOCB as defined in this chapter. The former unit is identical with our Maputaland Coastal Belt (with all imbedded intrazonal and azonal vegetation units), while the latter extends westwards beyond the limits of the southernmost vegetation unit within the IOCB (CB 5 Transkei Coastal Belt) and incorporates also the coastal belt between the Buffels River (East London) and Port Elizabeth. We consider the classification of the coastal belt of the Albany Thicket Biome into the KwaZulu-Natal-Cape Coastal Forest Mosaic as not justified. The latter portion of the coast has a warm-temperate character, carries climax vegetation (Albany Thickets), various coastal vegetation types on the adjacent seashore, strandveld (Vlok & Euston-Brown 2002, Vlok et al. 2003) as well as forest vegetation (Von Maltitz et al. 2003).

The IOCB is a climatically, ecologically and biogeographically peculiar region that deserves standing on its own at the level of biome within the scope of the South African vegetation. It is the southernmost, hence marginal, outlier of the East African Tropical Coastal Forest (Burgess et al. 1996, 1998, Burgess & Clarke 2000)—a member of the global Tropical and Subtropical Moist Forest Biome. As such it can be classified as the 'Subtropical Coastal Forest Biome'—an interesting geographical analogue of the 'Mata Atlântica', the subtropical coastal forest of the Atlantic seaboards of eastern Brazil (Hueck 1966), experiencing a fate very similar to the IOCB (Por 1992). The IOCB lost its natural 'forest face' due to intensive human influence dating since the Iron Age, but it demonstrates (under the climatic conditions of the current Holocene Interglacial) its clear tropical affinity.

The IOCB (or Subtropical Coastal Forest Biome) encompasses subtropical forest (Table 11.1) as zonal vegetation, accompanied by a series of intrazonal (edaphic grasslands) and azonal vegetation types. Within the latter, we count the azonal forest types (Northern Coastal Forest, Mangrove Forest, Swamp Forest, Lowveld Riverine Forest) and azonal nonforest vegetation units such as Subtropical Freshwater Wetland, Subtropical Dune Thicket and Subtropical Coastal Vegetation. For practical purposes we have singled out the forest vegetation (both zonal and azonal) of the IOCB and feature it, alongside other forest types, within Chapter 12. The nonforest vegetation is the subject of Chapters 13 and 14. The vegetation units in this particular chapter include the edaphic grassland units (Maputaland Wooded Grasslands, Pondoland-Ugu Sandstone Coastal Sourveld) as well as a series of 'Coastal Belts' (CB 1, 3, 5) which feature, similar to AT 9 Albany Coastal Belt (but unlike the rest of the units of the National Vegetation Map), current rather than potential vegetation patterns. We presume that most of the CB 1, 3 and 5 were formed by subtropical forests

Table 11.1 Indian Ocean Coastal Belt (corresponding to Subtropical Coastal Forest Biome) as a composite of zonal, intrazonal and azonal vegetation units. For the discussion on the concepts related to zonality, see Chapter 13 on 'Inland Azonal Vegetation'.

Vegetation Unit	Extent (km²)	Zonality status
FOz 7 Northern Coastal Forest [1,F]	467	zonal
FOz 8 Scarp Forest [4,F]	435	intrazonal (endemic)[6]
FOa 1 Lowveld Riverine Forest [F]	5	intrazonal/azonal[5]
FOa 2 Swamp Forest [F]	38	intrazonal/azonal[5]
FOa 3 Mangrove Forest [F]	33	intrazonal/azonal[5]
CB 4 Pondoland-Ugu Sandstone Coastal Sourveld	1297	intrazonal (endemic)[7]
CB 2 Maputaland Wooded Grassland	991	intrazonal (endemic)[7]
CB 1Maputaland Coastal Belt	4015	zonal[2]
CB 3 KwaZulu-Natal Coastal Belt	6293	zonal[2]
CB 5 Transkei Coastal Belt	1628	zonal[2]
AZe 3 Subtropical Estuarine Salt Marshes [C]	3	intrazonal/azonal[5]
AZs 3 Subtropical Dune Thicket [C]	20	intrazonal/azonal[5]
AZd 4 Subtropical Seashore Vegetation [C]	42	intrazonal/azonal[5]
AZf 6 Subtropical Freshwater Wetlands [A]	501	intrazonal/azonal[5]
AZa 7 Subtropical Alluvial Vegetation [A]	0[8]	intrazonal/azonal[5]
Freshwater Lakes[3]	91	not applicable
Coastal Lagoons[3]	465	not applicable

[1] incl. KwaZulu-Natal Coastal Forest and KwaZulu-Natal Dune Forest (Forest Types according to Von Maltitz et al. 2003)
[2] mapped as mosaic of primary (mainly edaphic) grassland, secondary grassland and succession thickets seral to the subtropical coastal forests (still found in patches and mapped as Northern Coastal Forest)
[3] not recognised as vegetation units (nonvegetated water bodies)
[4] incl. Pondoland Scarp Forest and Eastern Scarp Forest (Forest Types according to Von Maltitz et al. 2003)
[5] intrazonal on regional scale; azonal on continental scale
[6] endemism of this vegetation type relates to southern Africa (Scarp Forest occurs in Eastern Cape, KwaZulu-Natal and Mpumalanga, Swaziland, and possibly also in Mozambique)
[7] endemic to the Indian Ocean Coastal Belt
[8] none mapped in Indian Ocean Coastal Belt
[A] discussed in Chapter 13: Inland Azonal Vegetation
[C] discussed in Chapter 14: Coastal Vegetation
[F] discussed in Chapter 12: Afrotemperate, Subtropical and Azonal Forests

(see also the modelling study by Eeley et al. 1999), and possibly also by some more natural grassland. However, today these forests and natural grasslands have been replaced by a mosaic of secondary grasslands, seral thickets and bushveld or obliterated by agriculture and human settlements.

2. Ecology: Climate, Geology, Soils and Hydrology

2.1 Climate

The northern regions of the IOCB, close to the coast, have marginally nonseasonal (even) rainfall, with precipitation concentrated in summer. Richards Bay and St Lucia both have 41.6% of their annual mean rainfall in winter. There are approximately 14 rain days in June and July (Camp 1999b). The winter rains are associated with frontal systems from the south. Further south, the rainfall seasonality of the belt, also close to the sea, becomes clearly summer (Bailey 1979) in most places. The winter-rainfall proportion is 35.6% for Empangeni, 30.9% for Mount Edgecombe, 27.6% for Pinetown, 31.8% for Port Shepstone, 28.8% for Paddock, 32.7% for Cape Hermes Lighthouse (at Port St Johns) and 36.6% at Bashee Lighthouse (near the mouth of the Mbhashe River). The rainfall seasonality increases gradually inland towards neighbouring savanna vegetation types, for instance from about 33.6% on the border between Maputaland Coastal Belt and Zululand Thornveld (Riverview) and 26.7% on the border between KwaZulu-Natal Coastal Belt and Ngongoni Veld (Eshowe) to 28.0% (Mkuze) and 25.1% (Makatini Agr) well within savanna vegetation types. Strong summer-rainfall seasonality (<20% Bailey 1979) is only found in savanna types much further inland (e.g. in Thukela Valley Bushveld: Muden 19.3%). On the Transkei coast Cawe (1994) found that the proportion of winter rainfall is highest along the coastal belt closest to the sea; he refers to this as rainfall type D 'High rainfall with high winter rainfall' and he found this climate type to be confined to Acocks Veld Type 1.

In the KwaZulu-Natal part of the IOCB the mean annual rainfall ranges between 1 272 and 819 mm (Camp 1999b), while on the Eastern Cape coast the mean annual rainfall reaches 1 120 mm at Cape Hermes (Port St Johns) and 1 128 mm at Bashee Lighthouse (near the mouth of the Mbhashe River). The east-west gradient of annual precipitation is remarkably steep, especially in Maputaland, with around 1 200 mm on the coast, while about 60 km inland (Ndumo in the Savanna Biome) only about 60% of this amount occurs.

The mean annual temperature ranges relatively narrowly from about 22°C (in the north, near the Mozambique border) to 20.4°C at Mount Edgecombe (near Durban) to 19.9°C at Cape Hermes (Port St Johns) and to 19.1°C at the Bashee Lighthouse (near the mouth of the Mbhashe River). Summers are hot to very hot, while winters are mild, with hardly any frost (higher in the southernmost parts and then only mild).

Evaporation is roughly between 1 490 mm per annum on the South Coast (KwaZulu-Natal) and as high as 1 833 mm near Empangeni. Air humidity is high, especially along the coast in summer and may reach saturation point. Mean monthly relative humidity at 14:00 at Richards Bay varies from 72% in November to 59% in August. Moist summer heat may be a cause of discomfort, but it helps to maintain the temperature-sensitive and moisture-demanding tropical vegetation of the region—both indigenous as well as alien (crops and ornamental flora).

The region is under the combined influence of several wind systems (Bews 1920): rain-bearing southern and southwestern winds, eastern afternoon sea-breezes, and autumn anticyclonic föhns. The wind run was measured to be about 160 km per day in Empangeni. Cyclones originating over the Indian Ocean occasionally hit the region from the northeast, causing major climatic and hydrological havoc, for example the 1984 cyclone called Domoina.

The pronounced hot and damp tropical character of the climate of the IOCB in summer and its mild and slightly drier subtropical character in winter can be ascribed to several global and macroregional factors. Firstly, it is the unusual southbound shift of the Intertropical Convergence Zone in summer (Tyson 1986, Stokes et al. 1997). Secondly, it is the ameliorating influence of the warm Agulhas Current flowing close to the eastern coasts of South Africa. These factors control the deep intrusion of typical tropical biota on terra firma (terrestrial flora and fauna and associated biotic communities) on shore (global southernmost occurrence of mangroves) and offshore (global southernmost occurrence of corals: Ramsey 1994, Riegl 2003). Relative humidity of at least parts of the IOCB is remarkably similar to that in regions much further up the east coast of Africa within the tropics. For example, mean annual relative humidity for Durban is 79% (max. in February: 82% and min. in July: 73%) compared to 73% (max. in April: 82% and min. in October: 67%) for Dar-es-Salaam (Tanzania) and to 74% (max. in May: 79% and min. in February: 70%) for Mombasa (Kenya) (Müller 1982). Corresponding figures for relative humidity in Beira and especially Maputo (both in Mozambique) are considerably lower than for Durban.

2.2 Geology and Soils

The IOCB is geologically very heterogeneous, including Mokolian-age granites and gneisses that form the basement rocks for

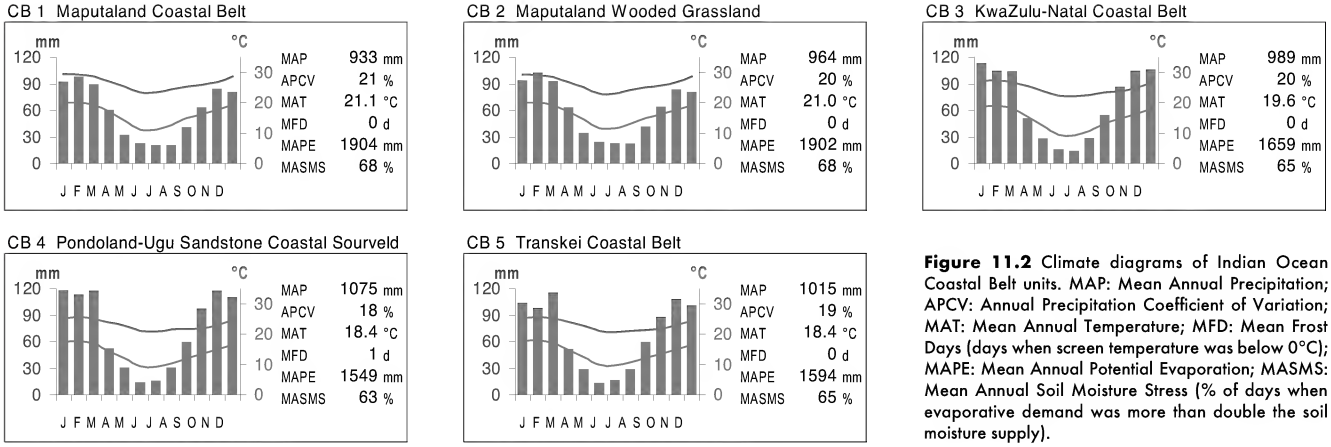

Figure 11.2 Climate diagrams of Indian Ocean Coastal Belt units. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days (days when screen temperature was below 0°C); MAPE: Mean Annual Potential Evaporation; MASMS: Mean Annual Soil Moisture Stress (% of days when evaporative demand was more than double the soil moisture supply).

sedimentary deposits spanning almost the entire Phanerozoic, from Ordovician to Recent times, and representing all levels of softness and the large variety of physical and chemical traits. The most striking, and for the region most characteristic, rocks are sandstones of the Msikaba Formation and those of the Natal Group (Thomas et al. 1992) which support endemic vegetation types such as Pondoland Scarp Forests (*sensu* Von Maltitz et al. 2003)—part of FOz 5 Scarp Forest (see Chapter 12) and CB 4 Pondoland-Ugu Sandstone Coastal Sourveld. On the Pondoland Wild Coast these sandstones descend to sea level, where they form dramatic coastal cliffs ornamented by numerous spectacular waterfalls. In KwaZulu-Natal, most of this belt turns inland and continues in the form of geological islands at variable distance from the coast. The Msikaba Sandstones have a high quartz content (70%–96%), with potassium feldspar and small amounts of mica occurring as well (Hobday & Mathew 1974). They are stratigraphically linked to the Witteberg Group of the Cape Supergroup (both are of Devonian age). The Natal Group is, like the Peninsula Formation sandstones of the Table Mountain Group, Ordovician. Like the sandstones building the core of the Cape Fold Belt mountains, the soils developing over both Msikaba and Natal Sandstones are sandy, highly leached, acidic and mostly very shallow. Rock outcrops are very frequent and dramatic scarps, krantzes and deep canyons are the typical accompanying geomorphological feature of this geological landscape.

The sandstone belt (spanning Port St Johns and Port Edward) divides the remainder of the IOCB into two distinct parts. The northernmost region (Maputaland) is a broad coastal plain consisting of a variety of Cenozoic to Recent marine sediments, mainly of Berea and Muzi Formations. A system of dune cordons can be traced on this plain, marking past sea-level stillstands of various ages. The oldest dune cordon (Ndumo) is more than 25 my old and occurs outside the IOCB proper. The coastal plain itself is of Plio-Pleistocene age (3 mya to 10 000 yrs ago; Davis 1976, Botha 1997) and is covered by sandy deposits, forming a high dune cordon all along the coast. Between Richards Bay and Umlalazi these dunes cover the interesting Port Dunford Formation (Oschadleus et al. 1996), 70 000 years old. Dystric regosols (formed by well-drained and acidic sands) are formed on elevated slopes and crests of the dune cordons. Humic gleysols (wet, acidic sands with abnormal accumulation of organic matter) are found in depressions—habitats with a high water table (Matthews et al. 1999). The rest of the KwaZulu-Natal coastal belt is a geologically complicated mosaic of Karoo Supergroup clastic sediments, metamorphic rocks of the Namibian Erathem and Cenozoic to Recent sediments.

Most of the Transkei Coastal Belt is built of Karoo sediments, including sandstone and mudstone of the Adelaide Subgroup, shale, mudstone and sandstone of the Ecca Group as well as tillites of the Dwyka Group; Jurassic dolerite intrusions occur in places.

Right at the coast, sand dune cordons have been formed or are being formed—these are calcareous young Quaternary sands derived from rocks of Cretaceous and Cenozoic origin. The sand dunes are massive and very high, especially in Maputaland as well as on the Zululand coast. They become rare in the southern part of the IOBC, where they are concentrated into small pockets at river mouths cutting though the steep coasts of Transkei.

2.3 Hydrology

The vegetation patterns of the IOCB are the result of intricate palaeofloral history, climate, geology, and last, but not least, hydrology. There are a number of azonal (or intrazonal) vegetation types controlled by temporal or semipermanent flooding embedded within the IOCB (Table 1). These include freshwater wetlands, estuaries, coastal lakes, mangroves, riverine and swamp forests, described in separate chapters on Inland Azonal Vegetation, Coastal Vegetation and Forests.

Maputaland is a particularly water-rich environment with, for example, spectacular coastal lagoons such as Kosi Bay and St Lucia, big lakes (Lake Sibaya is the largest freshwater lake in South Africa; Wright et al. 2000) and extensive swamps (Muzi Swamp, swamps of the Mkuze floodplain north of the St Lucia lagoon). In many places the ground-water table is very high. It feeds the marshes and pans and is regularly replenished by rain. Sandy substrates result in considerable fluctuations in ground-water level (Matthews et al. 1999). The existence of some of the grassland types, including the enigmatic Maputaland Wooded Grasslands and other 'edaphic' grasslands embedded within the Maputaland Coastal Belt and KwaZulu-Natal Coastal Belt, is linked to dynamics of the ground-water table and temporary surface flooding (e.g. Matthews et al. 1999).

3. Biogeographical Patterns: Past and Present

3.1 Palaeo-ecological Patterns

According to Maud (in Tinley 1985: 43), at least the Maputaland region must have been submerged approximately 10 mya as witnessed by Miocene and Pliocene sediments reaching up to 300 m above present sea level. Mid- and Upper Pliocene were characterised by uplift and tilting of the southern African subcontinent, resulting in formerly submerged areas (or some parts of them) becoming dry land. However, the areas that we define as parts of the current IOCB were formed only much later—through a series of Pleistocene marine regressions.

It is clear that the climate in southern Africa underwent dramatic changes during the Pliocene and Pleistocene (past 5 my) marked by about 21 climatic cycles (each approximately 100 000 yrs long) of alternation of dry/cold and wet/warm climates (Deacon 1983, Tyson 1986, Deacon & Lancaster 1988). Undoubtedly these changes shaped the face of South African vegetation and are supposed to have had major impacts on the vegetation, especially on the extremes of macroclimatic gradients. There is only scanty palaeo-ecological (palynological) information on the vegetation of the IOCB during the Last Interglacial (approximately 130 000–40 000 BP). Studies of a lignite layer embedded in the Port Dunford Formation between Umlalazi Lagoon near Mtunzini and Richards Bay (Scott et al. 1992, Oschadleus et al. 1996) suggest existence of a complex of palustrine vegetation probably surrounded by coastal freshwater lakes, and forest vegetation in which *Podocarpus* (most likely *Afrocarpus falcatus*) might have been dominant. These papers hypothesised that the yellowwood forest developed here after formation of the peat (turning lignite) layer, coinciding with the deposition of sand with lower organic content. An abundance of *Podocarpus* pollen was found also in the sediments of the Lake Teza (near Mtubatuba)—around 3 400 yrs BP. *Podocarpus* contributed up to 20% of pollen found in the studied profile (Scott & Steenkamp 1996) deposited since the early Holocene. Scott & Steenkamp (1996) further imply that the *Podocarpus* pollen came from an 'original coastal woodland environment'. Unlike Port Dunford, in the surroundings of Lake Teza, *Podocarpus* was replaced by local swampy elements. Whatever the direction of the replacement, both studied localities suggest a spatial and temporal link between swamp vegetation and (presumably) *Podocarpus*-dominated

vegetation. Incidentally, it is the Swamp Forest, which supports (probably relictual) populations of afrotemperate tree elements such as *Apodytes dimidiata, Ilex mitis, Rapanea melanophloeos, Peddiea africana, Afrocarpus falcatus, Psychotria capensis* and *Scutia myrtina* (Wessels 1991). *Afrocarpus falcatus* occurs in the IOCB not only in the Scarp Forest (which shows a number of transitional traits between coastal and afrotemperate forests; see Chapter 12), but also in subtropical Coastal Forest (Lubbe 1997, Van Wyk & Smith 2001). Mazus (2000) added some more palynological data from the KwaZulu-Natal coastal peatlands and confirmed that *Podocarpus* has been abundant, especially in times when the regional climate during the Last Glacial was presumably wetter (70 000–34 000 BP and 14 000–5 000 BP). Botha et al. (1992) found *Podocarpus* pollen to be abundant in buried paleosols from cooler and wetter periods of the Late Pleistocene Hypothermal, but their locality is situated almost 1 000 m higher than the coastal peat deposits. Does the abundant occurrence (and dominance at the Port Dunford site) of *Podocarpus* in the pollen spectra mean (as argued for instance by Mazus 2000) that the coastal belt between Richards Bay and Umlalazi (and even further north as far as the Muzi Swamp) supported forests of afrotemperate nature? Not necessarily, as the tree species known today as 'afrotemperate' (including both genera *Podocarpus* and *Afrocarpus*) might rather be relicts of temporary migrations (or dispersal) from afromontane localities during wetter periods to palustrine coastal forests. The afrotemperate elements found within the IOCB today are exclusive to the Swamp Forests (Venter 1972, Lubbe 1997). These, as we know them today, '(sub)tropical' Swamp Forests might have acquired a more 'afrotemperate' face due to the increase of cover of *Podocarpus/Afrocarpus* in these habitats during cooler (but sufficiently wet) periods.

The vegetation landscapes of the IOCB, in concert with other biomes of southern Africa, underwent major changes as a response to a drop in temperature, reaching its minimum at about 18 000 yrs BP, at Late Glacial Maximum (LGM). This period is known to be not only cold (on average 5–6°C lower than today, Botha et al. 1992), but also drier—with precipitation as low as 40–70% of the present mean. The Indian Ocean seaboards of South Africa were much cooler and drier than today, owing also to the lower sea-surface temperatures (Van Zinderen Bakker 1982) and weaker and shallower Agulhas Current (Prell et al. 1980). Low precipitation and concentration of water in ice shields can cause a decrease of sea level by about 120 m. At the Indian Ocean seaboards, this resulted in reworking of the coastal dune cordons.

Following the LGM, climate ameliorated rather rapidly and wetter conditions re-established in the IOCB, sometimes between 17 000–15 000 BP (Tyson 1986). Along the time axis towards the present time, the temperature kept rising and around 7 000 BP it reached its alti-thermal (Tyson 1986, Deacon & Lancaster 1988, Partridge et al. 1990).

A new dune cordon was built and formed a corridor allowing (sub)tropical flora to migrate southwards together with the southward shift of the Intertropical Convergence Zone. It was supposedly during this period (between 15 000 to 7 000 BP) when the subtropical woody vegetation of the IOCB (as we know it today) staged its come-back or re-established here. In the process, the IOCB—the youngest biome in South Africa—was born.

3.2 Current Biogeographical Patterns

Biogeographically the IOCB region (and, unfortunately, also much of its deep hinterland) has been classified as Tongaland-Pondoland Regional Mosaic, spanning the coastal regions between Port Elizabeth and Xai Xai at the Limpopo River mouth in Mozambique and including regions such as the former Albany District, coastal hinterland as deep as Pietermaritzburg and Nongoma, most of Swaziland and the southern Lowveld (Moll & White 1978, White 1983). In a decisively altered version this region was redefined by Van Wyk (1994; see also Van Wyk & Smith 2001), setting the southernmost border at the Buffels River (albeit with reservations) and by including coastal plains of the Eastern Cape as far as Queenstown and piedmonts of the Southern Berg and further north all regions as far as the Low Drakensberg. Van Wyk (1994) renamed this unit to become the 'Maputaland-Pondoland Region', which is claimed to encompass two Centres of Endemism (CE), namely the Pondoland CE and Maputaland CE. Clarke (1998) reclassified the Maputaland CE by incorporating it into his Swahili-Maputaland Regional Transition Zone.

The extent of the Pondoland CE corresponds well with the core of our vegetation unit CB 4 Pondoland-Ugu Sandstone Coastal Sourveld. The Maputaland CE is heterogeneous in terms of vegetation (as well as in terms of age of incorporated vegetation units). It incorporates the CB 1 Maputaland Coastal Belt, CB 2 Maputaland Wooded Grasslands as well as part of the accompanying forest types (see Chapter 12) and azonal wetland and coastal vegetation. Unlike Van Wyk & Smith (2001), we do not recognise the Lebombo Mountains as part of the Maputaland CE.

The IOCB appears to be the youngest biome in our region and still two regional centres of endemism (Pondoland and Maputaland) coincide with the extent of the IOCB. How does this fit with the relatively 'recent' dramatic climatic (and palaeoecological) scenarios that led to formation of this new biome? We suggest that the explanation lies in the azonality (or intrazonality) of the habitats supporting endemic flora. The endemic-rich coastal sourveld is limited to special geology (sandstones of Msikaba Formation) supporting nutrient-stressed soils, and in a way simulating the geological and pedological conditions typical of the Fynbos (Van Wyk 1989, 1990a, 1994, Van Wyk & Smith 2001). The evolutionary old endemics of the Pondoland are concentrated either to scarp (and deep-gorge) forests, which undoubtedly must have undergone major shrinkage during the LGM (as well as during the much earlier Pleistocene glacials), but were able to recover from local, well-sheltered refugia. These forests, too, are confined largely to the same types of sandstones and to a lesser extent also to granites (Ongoye Forest near Empangeni). The endemics of Maputaland are largely neo-endemics—the infraspecific status of many of them suggests a very recent origin (Van Wyk & Smith 2001). Within the IOCB proper, they are almost exclusively found in azonal vegetation types, such as CB 2 Maputaland Wooded Grassland. The occurrence of palaeo-endemics in the region (such as *Helichrysopsis septentrionale* in wooded grasslands, *Encephalartos ferox* in coastal thicket and coastal forest, and palustrine palm *Raphia australis*) demonstrates the ability of these taxa to resist dramatic climate changes. Resilience of habitats such as wooded grasslands and swamps might have also played a role in preserving these old relics.

The nature of regional endemism in the IOCB and the major phytogeographic links are discussed in detail by Moll & White (1978). These authors have established that the flora of the IOCB contains Zanzibar-Inhambane, Zambezi, Afromontane, Upland, Cape/Afromontane, Karoo-Namib and Guineo-Congolian linking elements as well as a separate category of 'chorological and ecological transgressors' occurring in a wide range of vegetation types in southern Africa.

4. Present Status

Land use is primarily sugarcane farming (over 88% of the cultivated area; Camp 1999b) in the KwaZulu-Natal area of the biome and subsistence farming in the Eastern Cape. Subsistence farming areas from Port Shepstone in southern KwaZulu-Natal to the KwaZulu-Natal/Mozambique border are undergoing rapid development to small-scale sugarcane farming and small-scale commercial tree farming. This is resulting in the loss of vast areas of natural vegetation.

The coastline of KwaZulu-Natal south of St Lucia Estuary is highly developed, with only small isolated occurrences of natural vegetation. A considerable area of the Forest Biome is embedded within this geographical area. In contrast, the coastline of the Transkei is little transformed and there are many natural grassland patches outside formal nature reserves. The IOCB supports the highest human population concentrations on the eastern seaboard.

About 39% of the IOCB's geographical area has been transformed. However, there is a considerable range in the levels of transformation within and between vegetation types, with corresponding implications for meeting conservation targets for biodiversity. South of the KwaZulu-Natal/Eastern Cape border there remain extensive areas of natural vegetation and consequently conservation targets are likely to be attainable, but throughout the KwaZulu-Natal portion of the biome critically high levels of transformation make it very difficult to meet conservation targets.

Approximately 7% of the IOCB is formally protected in statutory reserves. However, this is disproportionately spread between the five vegetation units, one of them with less than 1% protected.

5. Threats to Natural Vegetation

Cultivation and afforestation are the greatest threats. Extensive areas, in many cases previously grazed on a subsistence basis, are undergoing rapid development to small-scale sugarcane farming and small-scale commercial tree farming. Outgrow projects of large companies coupled with large-scale government water supply schemes and other agricultural incentive schemes are promoting small-scale commercial farming in areas hitherto not available for these land uses.

Alien invasive plants are a major and growing threat. Replacement of natural plant communities to ones dominated by alien plants is prevalent throughout the geographical area of the biome and the vegetation units. *Chromolaena odorata* is the main problem plant. Severe loss of browsing and grazing for both domestic livestock and wildlife is commonplace. Where landowners can afford it, large amounts of money are often allocated to control of invasive plants. However, in poor areas infestation is usually so severe that little indigenous vegetation survives.

Extensive areas of subsistence farming often occur in underdeveloped areas between commercial agriculture. Grasslands are often burnt indiscriminately to the disadvantage of many natural plant communities and consequently of wildlife in general. This also tends to affect the ecological functioning of bushclump and forest margins. Traditional hunting is sometimes the cause of such fires.

Urbanisation is rapidly expanding into the few natural areas remaining near the many development nodes. Some of the most prolific examples are to be seen at Richards Bay, Durban, Scottburgh, Port Shepstone and Margate.

The Pondoland coastal area faces the threat of dune mining and the construction of a new N2 toll road.

6. Action: Conservation and Management of Resources

In terms of the conditions of a World Heritage Site, the Greater St Lucia Wetland Park is run by a Wetlands Authority. The management of the wildlife has been delegated to the provincial nature conservation agency Ezemvelo KZN Wildlife. In addition, many natural areas of Maputaland are benefiting from the Lubombo Spatial Development Initiative. This applies mainly to the Savanna Biome west of the IOCB and is discussed in that chapter. It places much of the northern part of the IOCB in the fortunate position of being under well-developed, secure management structures.

Ezemvelo KZN Wildlife is mandated to attend to nature conservation needs throughout the KwaZulu-Natal part of the IOCB. The southern half of the coastal belt is, however, poorly provided for in terms of well-integrated land use planning. To this end, Ezemvelo KZN Wildlife has developed detailed conservation planning protocols based on systematic conservation planning approaches. This includes the modelling of irreplaceable areas. These are then embedded in the Municipal Spatial Development Frameworks. Other land use planning controls that are important for the conservation of natural vegetation include the Durban Metro Municipal Open Space System (D-MOSS).

In the Eastern Cape a project integrating conservation and development on the Wild Coast (most of the Transkei coastline and incorporating most of Pondoland), has been launched by the Eastern Cape Department of Economic, Environmental Affairs and Tourism and the Wilderness Foundation (*The Herald News* 29/7/2004). The project will build on the 1997 Spatial Development Initiative and is being modelled on the STEP Programme for the Thicket vegetation type. The Wild Coast Conservation and Development Project has initiated actions that include conservation assessment, strategic environmental assessment, an integrated land use plan that nests biodiversity conservation objectives into the regional sustainable development framework, a conservation strategy and action plan, participation in the Global Environmental Facility (GEF) funding proposals, and implementation programme for the Wild Coast in conjunction with the national Department of Environmental Affairs and Tourism. The long-term goal of the GEF project is: Representative system of protected areas in priority bioregions is established effectively, managed and contributes to sustainable development. The GEF project objective is: An effective network of protected areas is established on the Wild Coast and provides tested co-management models for replication. The possible creation of a Pondoland Park will form part of this planning.

7. Further Research Challenges

Maputaland became a focus of interest of geologists (Botha 1997, Maud & Botha 2000, Wright et al. 2000) as a prime example of evolution of coastal plains, of vegetation ecologists owing to interesting sources of palaeo-ecological data (Scott et al. 1992, Scott & Steenkamp 1996, Mazus 2000), of biogeographers because of the key importance of the Belt for southbound plant and animal migrations (White 1983, Lawes 1990) and of vegetation ecologists for the diversity of vegetation types reflecting intricate soil and hydrological patterns as well

as regional climatic gradients (Moll & White 1978, Moll 1978, 1980, Lubbe 1997). The Maputaland coast, and to some extent also southern stretches of the KwaZulu-Natal coast, with its mosaic of grasslands, thickets and coastal forests, faces human pressures ranging from over-development due to increasing tourism, urban sprawl to coastal mining. These pressures have generated considerable interest in biological research (Weisser 1978, 1987, Weisser & Marques 1979, Ward 1980). Our knowledge of floristic treasures of Pondoland is increasing (Van Wyk 1990b, Van Wyk & Smith 2001), and the region continues to yield new surprises, such as the discovery of a spectacular new *Clivia* species (Murray et al. 2004). There is still no comprehensive vegetation monograph for either the Pondoland coastal sourveld or of the famous Pondoland subtropical forests. Within the IOCB, the biota of the remainder of the Transkei coast is poorly known. More research in all aspects of ecology should be initiated here, especially in the light of the increased interest of developers targeting this coastal stretch.

8. Descriptions of Vegetation Units

CB 1 Maputaland Coastal Belt

VT 1 Coastal Forest and Thornveld (97%) (Acocks 1953). LR 23 Coastal Bushveld-Grassland (86%) (Low & Rebelo 1996). BRG 1 Moist Coast Forest Thorn & Palm Veld (59%) (Camp 1999a, b). Coast Grassveld p.p. & Palm Veld p.p. (Moll 1978, 1980).

Distribution KwaZulu-Natal Province (and continuing also in southern Mozambique): Up to 35 km broad strip along the coast of the Indian Ocean stretching from the Mozambique border in the north to Mtunzini in the south. Altitude varies from about 20–120 m.

Vegetation & Landscape Features Flat coastal plain originally probably densely forested in places with a wide range of interspersed nonforest plant communities including dry grasslands (which include palm veld where special conditions prevail), hygrophilous grasslands and thicket groups. Today the vegetation landscape is composed of pockets of various forest types (separated into different vegetation units), thicket, primary and secondary grasslands, extensive timber plantations and cane fields. The belt of the IOCB immediately inland (only a few kilometres wide) and parallel to the line of Northern Coastal Forest has a characteristic appearance of very irregular dunes with generally open vegetation and *Syzygium cordatum* dotted prominently on the dunes, with many irregular dune slacks interspersed. There is little to suggest that this part of the vegetation, e.g. between Lake Sibaya and Kosi Lake, is secondary. The peculiar CB 2 Maputaland Wooded Grassland—still another vegetation unit embedded within the geographical extent of the Maputaland Coastal Belt—is treated as a separate vegetation unit (see below).

Geology & Soils Up to about 18 000 yrs old Quaternary sediments of marine origin—mainly yellowish and argillaceous redistributed sands (Berea and Muzi Formations of the Maputaland Group, respectively). Soils nutritionally very poor and well leached, except in the interdune depressions where organic-rich soils are sometimes found. The dominant land types include Hb and Ha, with some contribution of Db land type.

Climate Weak rainfall seasonality near the coast tending toward summer rainfall towards the interior. Relatively high precipitation attaining annual values up to 1 200 mm in coastal localities, decreasing rapidly to the interior. High humidity and temperature. Mean maximum and minimum monthly temperature for Lake St Lucia Research Centre are 35.3°C and 5.5°C (for January and June, respectively). No incidence of frost. See also climate diagram for CB 1 Maputaland Coastal Belt (Figure 11.2).

Important Taxa Low Shrubs: *Agathisanthemum bojeri* (d), *Helichrysum kraussii* (d), *Tephrosia longipes*. Small Trees & Tall Shrubs: *Syzygium cordatum* (d), *Acacia natalitia*, *Annona senegalensis*, *Apodytes dimidiata*, *Bridelia cathartica*, *Canthium inerme*, *Chrysanthemoides monilifera* subsp. *rotundata*, *Euclea natalensis* subsp. *natalensis*, *Ficus burtt-davyi*, *Kraussia floribunda*, *Phoenix reclinata*, *Rhus natalensis*, *Sclerocroton integerrimum*, *Strychnos spinosa*. Woody Climbers: *Abrus precatorius* subsp. *africanus*, *Smilax anceps*. Herbs: *Achyranthes aspera*, *Centella asiatica*, *Chamaecrista plumosa*, *Hermbstaedtia odorata* var. *aurantiaca*, *Vernonia centaureoides*, *V. oligocephala*. Graminoids: *Diheteropogon amplectens* (d), *Eragrostis sclerantha* (d), *Ischaemum fasciculatum* (d), *Themeda triandra* (d), *Urelytrum agropyroides* (d), *Aristida stipitata* subsp. *graciliflora*, *Cymbopogon pospischilii*, *Elionurus muticus*, *Eragrostis inamoena*, *E. lappula*, *Sporobolus subulatus*, *Trachypogon spicatus*, *Trichoneura grandiglumis*, *Tristachya leucothrix*.

Biogeographically Important Taxa ([C]Coastal belt element, [F]Generic fynbos element, [ILP]Isolated lowland populations, [M]Maputaland endemic, [N]Northern distribution limit, [S]Southern distribution limit) Geoxylic Suffrutex: *Diospyros galpinii*[S]. Low Shrubs: *Indigofera williamsonii*[C], *Rhus kwazuluana*[M], *Stylosanthes fruticosa*[S]. Small Trees & Tall Shrubs: *Hyphaene coriacea*[S] (d), *Ozoroa obovata*[S], *Rhus nebulosa*[C], *Synaptolepis kirkii*[M]. Woody Climber: *Dalbergia obovata*[C]. Herbs: *Helichrysopsis septentrionale*[M], *Helichrysum tongense*[C], *H. cymosum* subsp. *cymosum*[N], *Nidorella tongensis*[M], *Senecio ngoyanus*[C], *Vernonia natalensis*[ILP]. Megaherb: *Strelitzia nicolai*[C] (d). Succulent Herb: *Orbea longidens*[M]. Semiparasitic Herb: *Striga junodii*[S]. Graminoid: *Monocymbium ceresiiforme*[ILP].

L. Mucina

Figure 11.3 CB 1 Maputaland Coastal Belt: Seasonally wet grasslands of the Palm Veld (with *Hyphaene coriacea*) near KaNgwanase in Maputaland, northern KwaZulu-Natal.

Endemic Taxa ([F]Generic fynbos element) Herbs: *Helichrysum adenocarpum* subsp. *ammophilum*, *Vahlia capensis* subsp. *vulgaris* var. *longifolia*. Geophytic Herbs: *Asclepias gordon-grayae*, *Kniphofia leucocephala*, *Raphionacme lucens*. Graminoid: *Restio zuluensis*[F] (d).

Conservation Vulnerable. Target 25%. 15% statutorily conserved in the Greater St Lucia Wetland Park as well as in Sileza, Enseleni and Amathikulu Nature Reserves. More than 30% transformed for plantations and cultivation and by urban sprawl. Aliens include scattered populations of *Chromolaena odorata* and *Lantana camara*. Erosion is mostly very low. This vegetation type has a relatively high number of plant taxa at the southernmost and northernmost limits of their distribution range—the occurrence of widely disjunct or outlier populations increases the conservation value of this vegetation type.

Remark 1 The primary grasslands of interdune depressions and seasonally waterlogged bottomlands of the Maputaland were classified by Matthews et al. (1999) as the *Eragrostis lappula–Helichrysopsis septentrionalis* and *Ischaemum fasciculatum–Eragrostis inamoena* hygrophilous grasslands, and by Lubbe (1997) as *Ischaemum fasciculatum–Centella asiatica* hygrophilous grassland. Like the Maputaland Wooded Grasslands, these primary grasslands are home to a number of Maputaland endemics such as the enigmatic *Restio zuluensis* and *Helichrysopsis septentrionale*.

Remark 2 Most of the Maputaland Coastal Belt is agricultural land and very little of this unit remains in a natural state in the South African part of Maputaland. A much larger area of well-preserved coastal belt is found in Mozambique.

References Venter (1972), Moll (1972, 1978, 1980), Moll & White (1978), Weisser (1978, 1987), Weisser & Marques (1979), Lubbe (1997), Camp (1999a, b), Matthews et al. (1999), Smith (2001), Van Wyk & Smith (2001).

CB 2 Maputaland Wooded Grassland

VT 1 Coastal Forest and Thornveld (100%) (Acocks 1953). LR 23 Coastal Bushveld–Grassland (98%) (Low & Rebelo 1996). BRG 1 Moist Coast Forest Thorn & Palm Veld (61%) (Camp 1999a, b). Incl. *Themedo–Salacietum* Myre (1964).

Distribution KwaZulu-Natal Province and southern Mozambique: In South Africa from the Mozambique border near KwaNgwanase southwards to Sileza, Sibaya, Mseleni, Mbazwana, Sodwana Bay, Ozabeni, eastern and western shores of Lake St Lucia, KwaMbonambi and as far south as near Richards Bay. Altitude varies from about 20–120 m.

Vegetation & Landscape Features Generally flat landscape of the Maputaland coastal plain supporting coastal sandy grasslands rich in geoxylic suffrutices, dwarf shrubs, small trees and very rich herbaceous flora. Excluded from this unit are the many interdune depression wetlands and hygrophilous grasslands neighbouring the wooded grasslands.

Geology & Soils Quaternary redistributed sand supporting yellowish redistributed sands of the Berea Formation (Maputaland Group). These are dystric regosols building dune crests, slopes and relatively high-lying level plains. Water table found at depth 1.6–2.0 m below surface (and slightly deeper) in average rainfall years. Ha is the overwhelmingly dominant land type, followed by Hb land type.

Climate Approximately the same as for the CB 1 Maputaland Coastal Belt (both units form an intricate regional mosaic). See also climate diagram for CB 2 Maputaland Wooded Grassland (Figure 11.2).

Important Taxa ([#]Suffrutex form) Geoxylic Suffrutices: *Parinari curatellifolia* (d), *Salacia kraussii* (d), *Ancylobotrys petersiana*, *Diospyros galpinii*, *Eugenia capensis*[#], *Syzygium cordatum*[#]. Graminoids: *Diheteropogon amplectens* (d), *Themeda triandra* (d), *Aristida stipitata* subsp. *graciliflora*, *Bewsia biflora*, *Cyperus obtusiflorus*, *C. tenax*, *Digitaria natalensis*, *Eustachya paspaloides*, *Setaria sphacelata*, *Sporobolus fimbriatus*, *S. subulatus*, *Urelytrum agropyroides*. Herb: *Chamaecrista plumosa*. *Geophytic Herb: Cyrtanthus galpinii*. Low Shrubs: *Helichrysum kraussii* (d), *Agathisanthemum bojeri*, *Crotalaria monteiroi* var. *monteiroi*. Small Trees & Tall Shrubs: *Acridocarpus natalitius* var. *linearifolius*, *Dichrostachys cinerea* subsp. *nyassana*, *Diospyros lycioides* subsp. *sericea*, *Hyphaene coriacea*, *Terminalia sericea*.

Biogeographically Important Taxa ([C]Coastal belt element, [M]Maputaland endemic, [S]Southern distribution limit) Geoxylic Suffrutices: *Eugenia albanensis*[C], *Gymnosporia markwardii*[M]; Graminoids: *Abildgaardia hygrophila*[C], *Cyperus natalensis*[C]. Herbs: *Helichrysopsis septentrionale*[M]; *Oxygonum robustum*[M], *Tricliceras mossambicense*[M]. Tall Shrub: *Grewia microthyrsa*[S]. Woody Climbers: *Albertisia delagoensis*[S], *Cissampelos hirta*[S].

Endemic Taxa ([#]Suffrutex form) Geoxylic Suffrutices: *Ochna* sp. nov., *Syzygium cordatum*[#]. Succulent Herb: *Aloe* sp. nov. (*Strey 5100 PRE*). Geophytic Herb: *Brachystelma vahrmeijeri*.

Conservation Endangered. Target 25%. About 17% statutorily conserved mainly in the Greater St Lucia Wetland Park. Some 46% transformed mostly for plantations and partly for cultivated land. The southern half of the area is not protected and it is here that over 90% of the extent of the vegetation type has been transformed—mostly to pulpwood timber plantations, cane fields and informal settlements. Aliens include scattered populations of *Chromolaena odorata* and *Lantana camara*.

W.S. Matthews

Figure 11.4 CB 2 Maputaland Wooded Grassland: Wooded grassland in Maputaland (northern KwaZulu-Natal) with prominent (silvery leaves) undescribed species of geoxylic suffrutex (*Ozoroa* sp. nov.).

Remarks This type is an example of the famous 'underground forests of Africa' (White 1976) characterised by plants with sometimes enormous underground woody parts connecting apparently separate dwarf shrubs or even with only tufts of leaves above ground. This growth form is called a geoxylic suffrutex (dwarf woody plant with annual or short-lived above-ground woody shoots sprouting from massive underground 'stem') (White 1976, Matthews et al. 1999, Van Wyk & Smith 2001). Some of the taxa occur naturally only as geoxylic suffrutices, while in some, generally more widely distributed taxa (incl. *Eugenia capensis, Syzygium cordatum*) suffrutex forms occur in these habitats. Several hypotheses have been suggested to explain the existence of this enigmatic vegetation type as well as the peculiar concentration of the geoxylic suffrutices. Fire-resistance and adaptation to high groundwater tables have been proposed most often (see White 1976, Matthews et al. 1999), but none of these (and other) explanations have been accompanied by conclusive evidence. Species with the geoxylic suffrutex form are also found within many open and well-wooded savanna types including some with sandy substrate where there is commonly a higher investment in below-ground organs.

References Myre (1964, 1971), White (1976, 1983), Moll (1978, 1980), Moll & White (1978), Van Wyk (1994, 1996), Lubbe (1997), Mathews et al. (1999), Smith (2001), Van Wyk & Smith (2001), Felton (2002).

CB 3 KwaZulu-Natal Coastal Belt

VT 1 Coastal Forest and Thornveld (81%) (Acocks 1953). LR 23 Coastal Bushveld–Grassland (62%) (Low & Rebelo 1996). BRG 1 Moist Coast Forest Thorn & Palm Veld (89%) (Camp 1999a, b).

Distribution KwaZulu-Natal Province: Long and in places broad coastal strip along the KwaZulu-Natal coast, from near Mtunzini in the north, via Durban to Margate and just short of Port Edward in the south. Altitude ranges from about 20–450 m.

Vegetation & Landscape Features Highly dissected undulating coastal plains which presumably used to be covered to a great extent with various types of subtropical coastal forest (the remnants of one of which are described in Chapter 12 as Northern Coastal Forest). Some primary grassland dominated by *Themeda triandra* still occurs in hilly, high-rainfall areas where pressure from natural fire and grazing regimes prevailed. At present the KwaZulu-Natal Coastal Belt is affected by an intricate mosaic of very extensive sugarcane fields, timber plantations and coastal holiday resorts, with interspersed secondary *Aristida* grasslands, thickets and patches of coastal thornveld.

Geology & Soils Ordovician Natal Group sandstone, Dwyka tillite, Ecca shale and Mapumulo gneiss (Mokolian) dominate the landscapes of the KwaZulu-Natal Coastal Belt. Weathering of old dunes has produced the red sand, called the Berea Red Sand, in places. The soils supported by the above-mentioned rocks are shallow over hard sandstones and deeper over younger, softer rocks. Fa land type dominates the area, while Ab land type is only of minor importance.

Climate Summer rainfall, but with some rainfall also in winter. High air humidity. No incidence of frost. Mean maximum and minimum monthly temperatures for Durban (airport) are 32.6°C and 5.8C and for Port Shepstone 30.6°C and 8.8°C (both for January and July, respectively). See also climate diagram for CB 3 KwaZulu-Natal Coastal Belt (Figure 11.2).

Important Taxa Graminoids: *Aristida junciformis* subsp. *galpinii* (d), *Digitaria eriantha* (d), *Panicum maximum* (d), *Themeda triandra* (d), *Alloteropsis semialata* subsp. *eckloniana*, *Cymbopogon caesius*, *C. nardus*, *Eragrostis curvula*, *Eulalia villosa*, *Hyparrhenia filipendula*, *Melinis repens*. Herbs: *Berkheya speciosa* subsp. *speciosa* (d), *Cyanotis speciosa* (d), *Senecio glaberrimus* (d), *Alepidea longifolia*, *Centella glabrata*, *Cephalaria oblongifolia*, *Chamaecrista mimosoides*, *Conostomium natalense*, *Crotalaria lanceolata*, *Dissotis canescens*, *Eriosema squarrosum*, *Gerbera ambigua*, *Hebenstretia comosa*, *Helichrysum cymosum* subsp. *cymosum*, *H. pallidum*, *Hibiscus pedunculatus*, *Hybanthus capensis*, *Indigofera hilaris*, *Pentanisia prunelloides* subsp. *latifolia*, *Senecio albanensis*, *S. bupleuroides*, *S. coronatus*, *S. rhyncholaenus*, *Sisyranthus imberbis*, *Stachys aethiopica*, *S. nigricans*, *Vernonia galpinii*, *V. oligocephala*. Geophytic Herbs: *Bulbine asphodeloides*, *Disa polygonoides*, *Hypoxis filiformis*, *Ledebouria floribunda*, *Pachycarpus asperifolius*, *Schizocarphus nervosus*, *Tritonia disticha*. Low Shrubs: *Clutia pulchella*, *Gnidia kraussiana*, *Phyllanthus glaucophyllus*, *Tephrosia polystachya*. Woody Climbers: *Abrus laevigatus*, *Asparagus racemosus*, *Smilax anceps*. Small Trees & Tall Shrubs: *Bridelia micrantha* (d), *Phoenix reclinata* (d), *Syzygium cordatum* (d), *Acacia natalitia*, *Albizia adianthifolia*, *Antidesma venosum*.

Biogeographically Important Taxa ([C]Coastal belt element, [S]Southern distribution limit) Graminoids: *Cyperus natalensis*[C], *Eragrostis lappula*[S]. Herbs: *Helichrysum longifolium*[C], *Selago tarachodes*[C], *Senecio dregeanus*[C], *Sphenostylis angustifolia*[S]. Geophytic Herbs: *Kniphofia gracilis*[C], *K. littoralis*[C], *K. rooperi*[C], *Pachystigma venosum*[S], *Zeuxine africana*[S]. Low Shrubs: *Helichrysum kraussii*[S] (d), *Agathisanthemum bojeri*[S], *Desmodium dregeanum*[C]. Megaherb: *Strelitzia nicolai*[C] (d). Geoxylic Suffrutices: *Ancylobotrys petersiana*[S], *Eugenia albanensis*[C], *Salacia kraussii*[S]. Small Trees & Tall Shrubs: *Anastrabe integerrima*[C] (d), *Acacia nilotica* subsp. *kraussiana*[S].

Endemic Taxa Herb: *Vernonia africana* (extinct). Geophytic Herb: *Kniphofia pauciflora*. Low Shrub: *Barleria natalensis* (extinct).

Conservation Endangered. Target 25%. Only very small part statutorily conserved in Ngoye, Mbumbazi and Vernon Crookes

L. Mucina

Figure 11.5 CB 3 KwaZulu-Natal Coastal Belt: Complex of primary species-rich grasslands and subtropical forests in Vernon Crookes Nature Reserve near Umzinto, KwaZulu-Natal.

Nature Reserves. About 50% transformed for cultivation, by urban sprawl and for road-building. Aliens include *Chromolaena odorata, Lantana camara, Melia azedarach* and *Solanum mauritianum*. Erosion is low and moderate.

References Edwards (1967), Moll & White (1978), Ward (1980), Roberts (1993), Camp (1999a, b), Heijnis (2004), Van der Linden et al. (2005).

CB 4 Pondoland-Ugu Sandstone Coastal Sourveld

VT 1 Coastal Forest and Thornveld (53%) (Acocks 1953). LR 48 Coastal Grassland (38%), LR 42 Moist Upland Grassland (28%) (Low & Rebelo 1996). BRG 1 Moist Coast Forest Thorn & Palm Veld p.p. Camp (1999a, b).

Distribution Eastern Cape and KwaZulu-Natal Provinces: Elevated coastal sandstone plateaus from Port St Johns on the Pondoland coast (Eastern Cape) to the vicinity of Port Shepstone (Ugu District, KwaZulu-Natal), incl. the sourveld of the well-known Oribi Gorge. Altitude ranges from about 0–600 m.

Vegetation & Landscape Features Coastal peneplains and partly undulating hills with flat table-lands and very steep slopes of river gorges. These sites support natural, species-rich grassland punctuated with scattered low shrubs or small trees (sometimes with bush clumps, especially in small gullies). Rocky outcrops and krantzes are common and dramatic sea-cliffs occur. Proteaceous trees (*Protea, Faurea*) can be locally common where conditions allow. Although less important here, the geoxylic suffrutex growth form (so typical of CB 2 Maputaland Wooded Grassland), is also represented in this sourveld.

Geology & Soils This unit is strictly delimited by its geology—it is built of hard, white, coarse-grained, siliceous quartz arenites (sandstones) of the Msikaba Formation of the Devonian Period (Thomas et al. 1992) giving rise to shallow, nutrient-poor (highly leached), skeletal, acidic sandy soils. Almost 80% of the area is classified as Fa land type, followed by Aa land type (10%).

Climate Summer rainfall with some rain in winter. No or very infrequent incidence of frost. Mean maximum and minimum monthly temperatures at Paddock (near Oribi Gorge in the north) are 32.2°C and 5.8°C (for January and July, respectively). The corresponding values for Cape Hermes Lighthouse (Port St Johns, in the south) are 29.5°C and 9.6°C for the same months. See also climate diagram for CB 4 Pondoland-Ugu Sandstone Coastal Sourveld (Figure 11.2).

Important Taxa Graminoids: *Alloteropsis semialata* subsp. *eckloniana* (d), *Aristida junciformis* subsp. *galpinii* (d), *Cymbopogon nardus* (d), *Themeda triandra* (d), *Tristachya leucothrix* (d), *Cyperus rupestris*, *Diheteropogon amplectens*, *Elionurus muticus*, *Eragrostis capensis*, *E. plana*, *Eulalia villosa*, *Heteropogon contortus*, *Panicum natalense*, *Trachypogon spicatus*. Herbs: *Chaetacanthus burchellii* (d), *Cyanotis speciosa* (d), *Helichrysum allioides* (d), *H. appendiculatum* (d), *H. krebsianum* (d), *H. spiralepis* (d), *Pentanisia angustifolia* (d), *Rhynchosia totta* (d), *Tephrosia macropoda* (d), *Berkheya speciosa* subsp. *speciosa*, *Cephalaria oblongifolia*, *Chamaecrista mimosoides*, *Eriosema salignum*, *Euphorbia ericoides*, *Helichrysum adenocarpum* subsp. *adenocarpum*, *H. aureum* var. *monocephalum*, *H. herbaceum*, *H. nudifolium* var. *pilosellum*, *H. pallidum*, *Indigofera hilaris*, *Pentanisia prunelloides* subsp. *latifolia*, *Pimpinella caffra*, *Vernonia capensis*. Geophytic Herbs: *Brachystelma tenellum*, *Eriospermum mackenii*. Low Shrubs: *Athrixia phylicoides*, *E. natalensis*, *E. natalitia*, *Gnidia anthylloides*, *G. kraussiana*, *G. nodiflora*, *Leonotis intermedia*, *Polygala hottentotta*. Small Trees & Tall Shrubs: *Euryops brevipapposus, Syzygium cordatum*. Semiparasitic Shrubs: *Thesium acutissimum*, *T. cupressoides*.

Biogeographically Important Taxa ([C]Coastal belt element, [E]Eastern isolated occurrence, [F]Generic fynbos element, [N]Northern distribution limit, [S]Southern distribution limit) Geoxylic Suffutex: *Gymnosporia vanwykii*[C]. Graminoids: *Loudetia simplex*[S] (d), *Calopsis paniculata*[F], *Tetraria robusta*[EF]. Herbs: *Helichrysum auriceps*[S], *H. natalitium*[S], *H. pannosum*[S], *Senecio dregeanus*[S], *S. rhyncholaenus*[S], *Berkheya insignis*[S], *Eriosema acuminatum*[C], *Helichrysum acutatum*[S], *H. longifolium*[C], *Peucedanum natalense*[C], *Roella glomerata*[F,C]. Geophytic Herbs: *Stenoglottis woodii*[S], *Asclepias patens*[C], *Disperis woodii*[C], *Kniphofia rooperi*[C]. Low Shrubs: *Senecio medley-woodii*[S], *Gnidia woodii*[S] (d), *Agathosma ovata*[F], *Erica aspalathifolia*[C], *Gnidia coriacea*[N], *Muraltia lancifolia*[F], *Pseudarthria hookeri*[F,S], *Relhania pungens*[F], *Stangeria eriopus*[C], *Syncolostemon rotundifolius*[C]. Geoxylic Suffutex: *Eriosemopsis subanisophylla*[S]. Small Trees & Tall Shrubs: *Faurea saligna*[S] (d), *Protea roupelliae* subsp. *roupelliae*[F] (d), *Encephalartos caffer*[N], *Loxostylis alata*[F], *Polygala gazensis* (isolated populations; also Inyanga), *Protea caffra* subsp. *caffra*[F], *P. simplex*[F], *Sclerocroton integerrimum*[S].

Endemic Taxa ([F]Generic fynbos element) Graminoid: *Fimbristylis variegata*. Herbs: *Eriosema umtamvunense*, *Geranium sparsiflorum*, *Lotononis bachmanniana*, *Selago peduncularis*, *Senecio erubescens* var. *incisus*, Geophytic Herbs: *Brachystelma australe*, *B. kerzneri*, *Watsonia inclinata*[F], *W. mtamvunae*[F]. Geoxylic Suffrutex: *Rhus acocksii*. Low Shrubs: *Leucadendron spissifolium* subsp. *natalense*[F] (d), *L. spissifolium* subsp. *oribinum*[F] (d), *Acalypha* sp. nov. (*Scott-Shaw 636 NU*), *Anthospermum streyi*, *Erica abbottii*, *E. cubica* var. *natalensis*[F], *Eriosema dregei*, *E. latifolium*, *E. luteopetalum*, *Euryops leiocarpus, Gnidia triplinervis*, *Leucadendron pondoense*[F], *Leucospermum innovans*[F], *Raspalia trigyna*[F], *Struthiola pondoensis*[F], *Syncolostemon ramulosus*, *Tephrosia bachmannii*. Tall Shrub: *Tephrosia pondoensis*.

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Figure 11.6 CB 4 Pondoland-Ugu Sandstone Coastal Sourveld: Pondoland sourveld on the edge of the Umtamvuna Gorge (near Port Edward, KwaZulu-Natal) with scattered trees of *Protea roupelliae* subsp. *roupelliae*. The dominant grasses are *Aristida junciformis* and *Loudetia simplex*.

Conservation Vulnerable (one of the top six vegetation units with the highest level of overall vulnerability in South Africa). Target 25%. Only about 7% statutorily conserved in the Mkambati Wildlife Reserve & Marine Sanctuary, and Umtamvuna, Mbumbazi and Oribi Gorge Nature Reserves. About 29% transformed for cultivation and plantations or by urban sprawl. In the Eastern Cape the land use is mostly subsistence farming. Erosion is very low and low.

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Figure 11.7 CB 5 Transkei Coastal Belt: Coastal grasslands and subtropical dune thickets near Umgazi River Mouth on the Transkei Coast (Eastern Cape Province).

Remark 1 The sandstone geology links Pondoland to other 'sourvelds' of South Africa. Pondoland forms the lowest step along a staircase of nutrient-poor geologies, comprising further the early Palaeozoic Natal Sandstones of the KwaZulu-Natal Midlands and the Late Triassic Clarens Sandstones of the Drakensberg (see also Van Wyk 1994). The occurrence of *Protea roupelliae, P. simplex*, *P. welwitschii, Erica natalitia*, *Helichrysum herbaceum, H. krebsianum, H. pannosum*, *Senecio rhyncholaenus* and *Schizoglossum atropurpureum* subsp. *virens* is indicative of this link. Pondoland is a crossroads of old migration routes and perhaps also a migration cul-de-sac (Van Wyk 1990a) of some of them. It shows not only a clear Drakensberg link, but also clear biogeographical (and geological) relationships to the Capensis through the occurrence of genera such as *Agathosma, Aristea, Athrixia, Calopsis, Cliffortia, Erica, Euryops, Leucadendron, Leucospermum, Loxostylis*, *Muraltia, Phylica, Podalyria, Prionium*, *Protea, Pseudoscolopia, Raspalia* (the only representative of the family Bruniaceae outside Capensis), *Restio*, *Relhania, Roella, Struthiola, Tetraria* and *Watsonia*. Some of these disjunctions occur at the species level (!): *Calopsis paniculata, Cliffortia odorata, Helichrysum diffusum, Loxostylis alata, Prionium serratum, Pseudoscolopia polyantha* and *Restio triticeus* (Midgley 1986, Carbutt & Edward 2001).

Remark 2 Slight depressions on the coastal plateau and rock pools on rocky outcrops support another suite of local endemics or biogeographically important taxa linked to hygromorphic soils. These include *Kniphofia rooperi, Podalyria velutina, Psoralea abbottii, Utricularia sandersonii, Watsonia bachmannii* and *W. pondoensis*.

References Moll & White (1978), Midgley (1986), Shackleton (1989, 1992), Shackleton (1990), Van Wyk (1990a, b), Shackleton et al. (1991), Abbott (1993), Shackleton & Shackleton (1994), Le Roux (1995), Glen (1996), Camp (1999a, b), Scott-Shaw (1999), Abbott et al. (2000), Carbutt & Edwards (2001), Van Wyk & Smith (2001).

CB 5 Transkei Coastal Belt

VT 1 Coastal Forest and Thornveld (84%) (Acocks 1953). LR 48 Coastal Grassland (37%), LR 23 Coastal Bushveld–Grassland (21%) (Low & Rebelo 1996).

Distribution Eastern Cape Province: Narrow coastal strip along the Wild Coast of Transkei and the Indian Ocean seaboards between Port St Johns (Egossa Interval) as far as the vicinity of the Great Kei River in the south. Altitude ranges from about 20–450 m.

Vegetation & Landscape Features The Transkei Coastal Belt is highly dissected, hilly coastal country with alternating steep slopes of low-reach river valleys and coastal ridges, sometimes broad enough to form small plains. A mosaic of grassland vegetation on the higher lying areas and characteristically on hill tops and upper hill slopes, alternating with bush clumps and small forests (considered as part of the vegetation unit FOz 5 Scarp Forest) is the major vegetation feature of the region. Most of the grasslands are undoubtedly secondary (result of forest clearing for cattle grazing). At the seaward border this vegetation mosaic is fringed by an interrupted belt of coastal dune thicket (considered as part of AZs 3 Subtropical Dune Thicket) and vegetation of young coastal habitats (dunes and beaches).

Geology & Soils Most of the area is built of Karoo Supergroup sediments including sandstone and mudstone of the Adelaide Subgroup, shale, mudstone and sandstone of the Ecca Group as well as tillite of the Dwyka group. Intrusions of Jurassic Karoo Dolerite Suite occur in places. The dominating soil forms are Glenrosa and Mispah. Fa land type dominates the area.

Climate Summer rainfall with some rain in winter (with up to 36.6% rainfall in winter at Bashee Lighthouse). No incidence of frost. Bashee Lighthouse recording a mean minimum temperature of 7.7°C in July. See also climate diagram for CB 5 Transkei Coastal Belt (Figure 11.2).

Important Taxa Graminoids: *Aristida junciformis* subsp. *galpinii* (d), *Stenotaphrum secundatum* (d), *Abildgaardia ovata*, *Cynodon dactylon*, *Dactyloctenium aegyptium*, *Ehrharta erecta* var. *erecta*, *Setaria plicatilis*, *S. sphacelata*, *Sporobolus africanus*. Herb: *Ipomoea cairica*. Geophytic Herb: *Bonatea speciosa* var. *antennifera*. Low Shrubs: *Anisodontea scabrosa*, *Passerina rigida*. Succulent Herb: *Crassula multicava* subsp. *multicava*. Small Trees & Tall Shrubs: *Acacia natalitia*, *Cestrum laevigatum*, *Grewia occidentalis* var. *occidentalis*. Succulent Tree: *Aloe ferox*.

Biogeographically Important Taxa (all coastal belt elements) Herb: *Stachys comosa*. Geophytic Herbs: *Asclepias patens*, *Strelitzia reginae*. Geoxylic Suffrutex: *Gymnosporia vanwykii*. Low Shrub: *Pavetta revoluta*.

Conservation Vulnerable. Target 25%. Only about 1% statutorily conserved, for example in Dwesa-Cwebe Wildlife Reserve & Marine Sanctuary, Silaka Wildlife Reserve and Hluleka Wildlife Reserve & Marine Sanctuary. About 20% transformed mainly for cultivation. Erosion is low and moderate.

Remarks The nonforest vegetation of the Transkei Coastal Belt is one of the most poorly studied vegetation types in the country.

References Acocks (1953, 1988), Moll & White (1978), Hoffman (1983).

9. Credits

The delimitation of the IOCB is based on K.G.T. Camp's map of Bioresource Groups for KwaZulu-Natal (Camp 1999a) within the borders of KwaZulu-Natal and on analysis based on interpretation of satellite-image data by D.B. Hoare in the Eastern Cape Province. The borders between CB 1 and CB 3 follow, to a great extent, the Camp's (1999a) map, but have been modified by C.R. Scott-Shaw and L. Mucina. The concept of CB 2 was jointly defined by W.S. Matthews, C.R. Scott-Shaw and L. Mucina, partly using the sources by Smith (2001) and Felton (2002). The concept of CB 3 resulted from fusion, as suggested by L. Mucina, and C.R. Scott-Shaw, of several units defined by Camp (1999a). The extent of CB 1 and CB 2 was partly defined also by mapping of the wetlands in Maputaland by M.C. Rutherford and L.W. Powrie. The extent of all IOCB vegetation units was also modified by the extent of the forest patches (see Chapter 12 for Credits).

The descriptions of CB 1 to CB 4 were a joint effort by L. Mucina and C.R. Scott Shaw; W.S. Matthews contributed to descriptions of CB 1 and CB 2; L. Mucina wrote the description of CB 5. The species lists were created by L. Mucina, C.R. Scott-Shaw and W.S. Matthews (the last-named for the Maputaland units). The introductory text was written by L. Mucina (sections 1 to 3), while C.R. Scott-Shaw contributed sections 4 to 7 of the introductory text. M.C. Rutherford contributed to sections 1 and 2 of the introductory text as well as to the climate and conservation sections of the vegetation unit descriptions. Table 11.1 was created jointly by L. Mucina, M.C. Rutherford and L.W. Powrie. The last-mentioned two authors also provided all climate diagrams. L. Mucina (with help of C.R. Scott-Shaw) collated the list of references. The photographs were contributed by W.S. Matthews and L. Mucina. M. Rouget, and others within the Directorate of Biodiversity Programmes, Policy & Planning of SANBI, provided quantitative information for each vegetation unit on conservation status and targets, areas currently conserved and areas transformed.

Ezemvelo KZN Wildlife kindly provided data on the extent of CB 2 as well as forest patches imbedded within the IOCB (Ezemvelo KZN Wildlife 2004. Metadatabase file: KwaZulu-Natal Forest Types, Dataset ID 550. Ezemvelo KZN Wildlife Scientific Services Branch, Pietermaritzburg). The wetlands were mapped using selected data from the National Land Cover 2000 project as well as digitising by L.W. Powrie from topographic maps of a number of wetlands in the Maputaland region. P.S. Goodman contributed valuable comments and C. Oellerman assisted C.R. Scott-Shaw with GIS work. R.A. Ward kindly corrected the geological terminology.

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'Die dag as die Bos tot niet is, is julle soos miere waarvan die nes uitmekaargeskop is. Al verskil is dat miere weer kan nes maak, maar julle kan nie weer die Bos maak nie. Het jy al gaan sit en uitreken hoeveel byle in hierdie bos kap? Hoeveel hande aan die grootword is om nóg te kap?'

from D. Matthee, 1984, Kringe in 'n bos. Tafelberg, Cape Town. p. 140

Afrotemperate, Subtropical and Azonal Forests

12

Ladislav Mucina and Coert J. Geldenhuys

with contributions by

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Figure 12.1 Typical moist form of indigenous warm-temperate forest (FOz 1 Southern Afrotemperate Forest) with tree fern *Cyathea capensis* (Diepwalle, Knysna, Western Cape).

L. Mucina

1. Introduction

Indigenous forest in South Africa is defined as 'a generally multilayered vegetation unit dominated by trees (largely evergreen or semi-deciduous), whose combined strata have overlapping crowns (i.e. the crown cover is 75% or more), and where graminoids in the herbaceous stratum (if present) are generally rare' (Bailey et al. 1999, Shackleton et al. 1999). Stand height ranges from high forest over 30 m to scrub forest with a height of just over 3 m. All indigenous forest of southern Africa is evergreen. Besides the obviously distinctive structure, the forests differ from the surrounding vegetation (fynbos, succulent thicket, grassland, savanna) by a large specific set of flora.

Forests occur scattered along the eastern and southern margins (Great Escarpment, mountain ranges and coastal lowlands) of South Africa, from the Soutpansberg in the north (inland, 22° 40′ S) and Maputaland in the east (coast, 27° S) to the Cape Peninsula in the west (34° S) (Figures 12.2 and 12.3). Typically they occur as a series of scattered small to very small patches (<10 ha), and most forests are smaller than 100 ha in size (Cooper 1985, Geldenhuys 1991, Midgley et al. 1997). In Mpumalanga the average forest patch size is 29 ha (Lötter et al. 2002). Most of the forest realm is an archipelago of forest islands imbedded within large-scale patches of biomes such as Fynbos, Albany Thicket, Grassland and Savanna. Today these patches form scarce, but typical elements of the Subtropical Coastal Forest Biome along the subtropical seaboards of the Indian Ocean. Only few larger forest complexes can be recognised in South Africa, and these are widely separated. The largest single forest (25 706 ha) is found in the surrounds of Knysna in the south; it forms part of a still larger complex of 60 560 ha at about 34° S, spanning 22° to 24° 30′ E (Geldenhuys 1991). The Amathole forest complex (Eastern Cape) covers 40 550 ha between latitudes 32° S and 33° S, and longitudes 26° E and 27° 30′ E (Thompson 1991). In the Pirie-Isidenge-Kubusie area there is a single patch larger than 8 000 ha (Phillipson 1987). In KwaZulu-Natal the Dukuduku Forest is the largest one (3 500 ha) (Cooper 1985). The Woodbush-De Hoek Forest (6 626 ha) is the largest forest patch along the Northern Escarpment (Scheepers 1978, Cooper 1985). Smaller and isolated, still significant forests occur in the regions between the larger forest complexes around Knysna, in the Amathole Mountains, in KwaZulu-Natal (both coastal and montane forests), and along the Northern Escarpment in Mpumalanga and Limpopo Provinces (Cooper 1985, Anonymous 1987, Von Breitenbach 1990, Geldenhuys 1991, Cooper & Swart 1992, Everard & Hardy 1993, Geldenhuys & Venter 2002).

The recent floristic-biogeographic classification of the indigenous forests of South Africa (Von Maltitz et al. 2003; further developed by L. Mucina, unpublished data) recognises 26 Forest Types grouped into 8 zonal groups and 1 azonal group. Table 12.1 features the correspondence between this detailed classification scheme and the system of vegetation units adopted here (see below). The vegetation units (as well as underlying Forest Types) were derived on the basis of real quadrate data, whereby the floristic composition, biogeographic relationship as well as climate, substrate and water dynamics

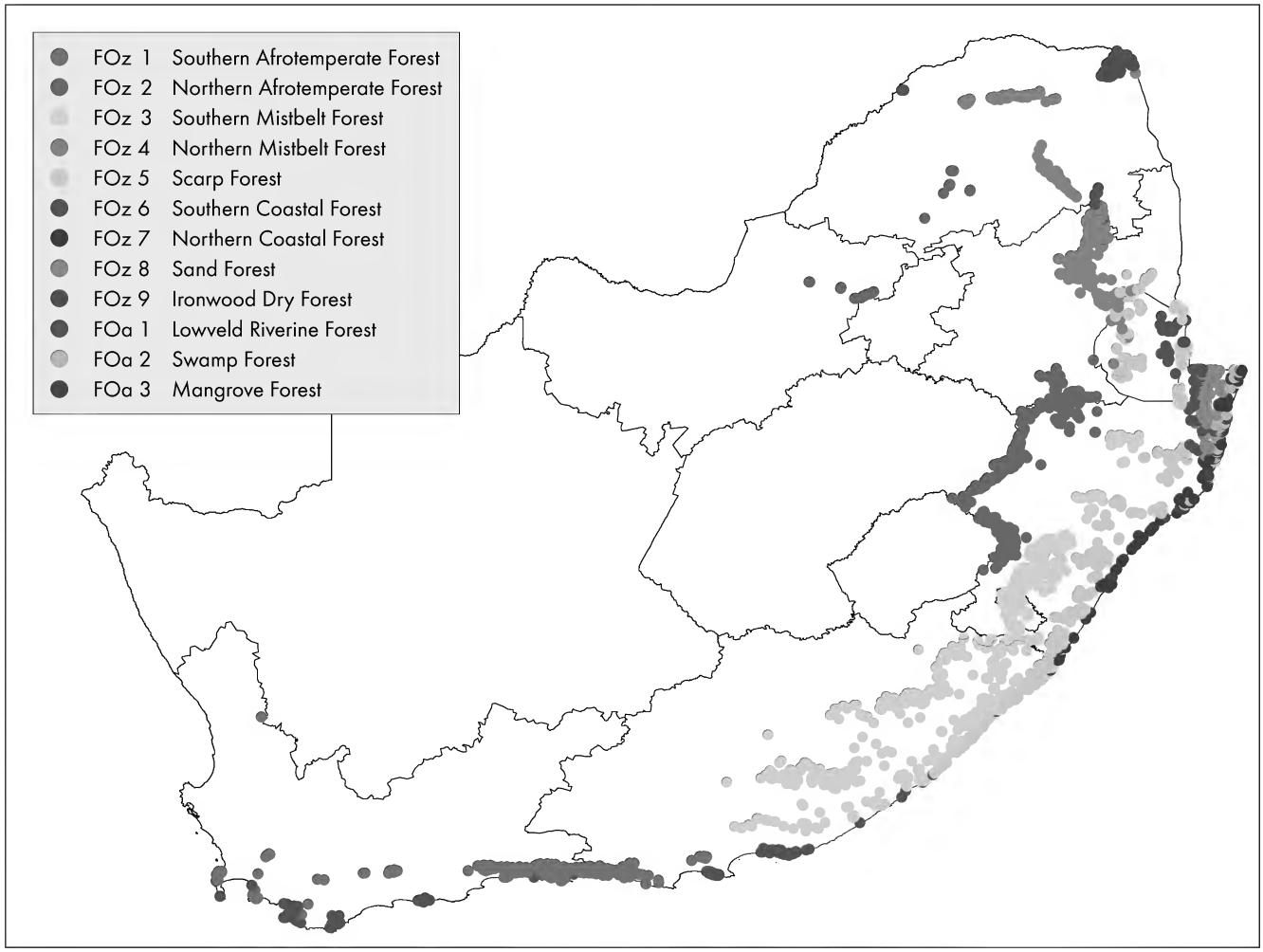


Figure 12.2 Distribution of the mapped vegetation units of the indigenous forests in South Africa and Swaziland.

Table 12.1 Crosswalk between the vegetation units adopted in this study and the National Forest Type Classification (modified after Von Maltitz et al. 2003; *not in the latter source). Zonality, intrazonality and azonality status is given for each forest type. The notion 'Savanna/Grassland' indicates that the particular forest type straddles the ecotone of both biomes.

Vegetation Units	National Forest Classification		Biome	Zonality
FOz 1 Southern Afrotemperate Forest	I	**Southern Afrotemperate Forest Group**		
	I1	Western Cape Talus Forest	Fynbos	intrazonal
	I2	Western Cape Afrotemperate Forest	Fynbos	intrazonal
	I3	Southern Cape Afrotemperate Forest	Afrotemperate Forest Biome	zonal
FOz 2 Northern Afrotemperate Forest	II	**Northern Afrotemperate Forest Group**		
	II1	Marekele Afromontane Forest	Savanna/Grassland	intrazonal
	II2	Northern Highveld Forest	Savanna/Grassland	intrazonal
	II3	Drakensberg Montane Forest	Grassland	intrazonal
	II4	Low Escarpment Mistbelt Forest	Grassland	intrazonal
FOz 3 Southern Mistbelt Forest	III	**Southern Mistbelt Forest Group**		
	III1	Eastern Mistbelt Forest	Grassland	intrazonal
	III2	Transkei Mistbelt Forest	Grassland	intrazonal
	III3	Amathole Mistbelt Forest	Grassland	intrazonal
FOz 4 Northern Mistbelt Forest	IV	**Northern Mistbelt Forest Group**		
	IV1	Northern Mistbelt Forest	Savanna/Grassland	intrazonal
	IV2	Mpumalanga Mistbelt Forest	Savanna/Grassland	intrazonal
FOz 5 Scarp Forest	V	**Scarp Forest Group**		
	V1	Eastern Scarp Forest	Savanna	intrazonal
	V2	Pondoland Scarp Forest	Indian Ocean Coastal Belt	zonal
	V3	Transkei Coastal Scarp Forest	Indian Ocean Coastal Belt	zonal
FOz 6 Southern Coastal Forest	VI	**Northern Coastal Forest Group**		
	VI1	Eastern Cape Dune Forest	Albany Thicket Biome	intrazonal
	VI2	Albany Coastal Forest	Albany Thicket Biome	intrazonal
	VI3	Western Cape Milkwood Forest	Fynbos	intrazonal
FOz 7 Northern Coastal Forest	VII	**Southern Coastal Forest Group**		
	VII1	KwaZulu-Natal Coastal Forest	Indian Ocean Coastal Belt	zonal
	VII2	KwaZulu-Natal Dune Forest	Indian Ocean Coastal Belt	zonal
FOz 8 Sand Forest	VIII	**Tropical Dry Forest Group***		
	VIII1	Licuati Sand Forest	Savanna	intrazonal
	VIII2	Nwambyia Sand Forest*	Savanna	intrazonal
FOz 9 Ironwood Dry Forest	VIII3	Ironwood Dry Forest*	Savanna	intrazonal
FOa 1 Lowveld Riverine Forest	A1	Lowveld Riverine Forest	Savanna	azonal
FOa 2 Swamp Forest	A2	Swamp Forest	Indian Ocean Coastal Belt	azonal
FOa 3 Mangrove Forest	A3	Mangrove Forest	Indian Ocean Coastal Belt	azonal

were taken into consideration. Details on the procedures of the classification of the indigenous forests into Forest Types, which led to the conceptualisation of the vegetation units in this study, are given by Mucina & Geldenhuys (2002).

Owing to the fragmented distribution of forests, the concept of zonality (as defined by Walter 1976) can be applied to forests only to a limited extent. The notion of a 'zone' relates (by definition) to biome (see Mucina 2000 for a definition). In the past the indigenous forests of South Africa were classified broadly into either two biomes, such as Afromontane forests and Coastal Belt forests (e.g. Huntley 1984) or just as a single biome (Forest Biome) as in Rutherford & Westfall (1986) and later in Low & Rebelo (1996). The latter notion was apparently motivated by purely structural rather than climatic-structural or floristic-biogeographic criteria.

In the case of the afromontane (White 1978) or more appropriately 'afrotemperate' (see Meadows & Linder 1989, 1993) forests, only one Forest Type would qualify as a part of a biome in its own right. It is the Forest Type I3: Southern Cape Afrotemperate Forests, which comprises the only forest area (the Knysna-Tsitsikamma Forest complex) of a biome dimension (Rutherford & Westfall 1986). Here these forests descend to sea level at 34° S latitude, providing a mirror image to the distribution pattern of warm-temperate forests of the northern hemisphere (Klötzli 1988) to such forests in Eastern Asia (e.g. Ohsawa 1993) and southwestern United States (Christensen 1988, Fujiwara & Box 1994, Haeupler 1994). The rest of the afrotemperate 'forest archipelago' in southern Africa should be seen as 'wreckage' of a warm-temperate biome occupying a narrow but probably formerly continuous belt along the steps of the Escarpment. These forests are imbedded (surrounded) by various temperate biomes such as Fynbos and Grassland or straddle ecotones between the Grassland and Savanna Biomes.

The evolutionary young Coastal Subtropical Forest Biome, known also as Indian Ocean Coastal Belt (Bews 1920, Moll & White 1978 and Huntley 1984) was probably dominated by a subtropical forest, of which only fragments classified as Forest Type VII1 KwaZulu-Natal Coastal Forests and VII2 KwaZulu-Natal Dune Forests remain. The other forest types rich in subtropical elements (the remainder of the Forest Group VI; Von Maltitz et al. 2003) are intrazonal—hence forming specific vegetation units embedded within (and unique to) well-defined vegetation zones (Table 12.1). Within South Africa the azonal Swamp Forests and Mangrove Forests (both of pronouncedly tropical character and distribution) are limited to the zone of the Indian Ocean Coastal Belt.

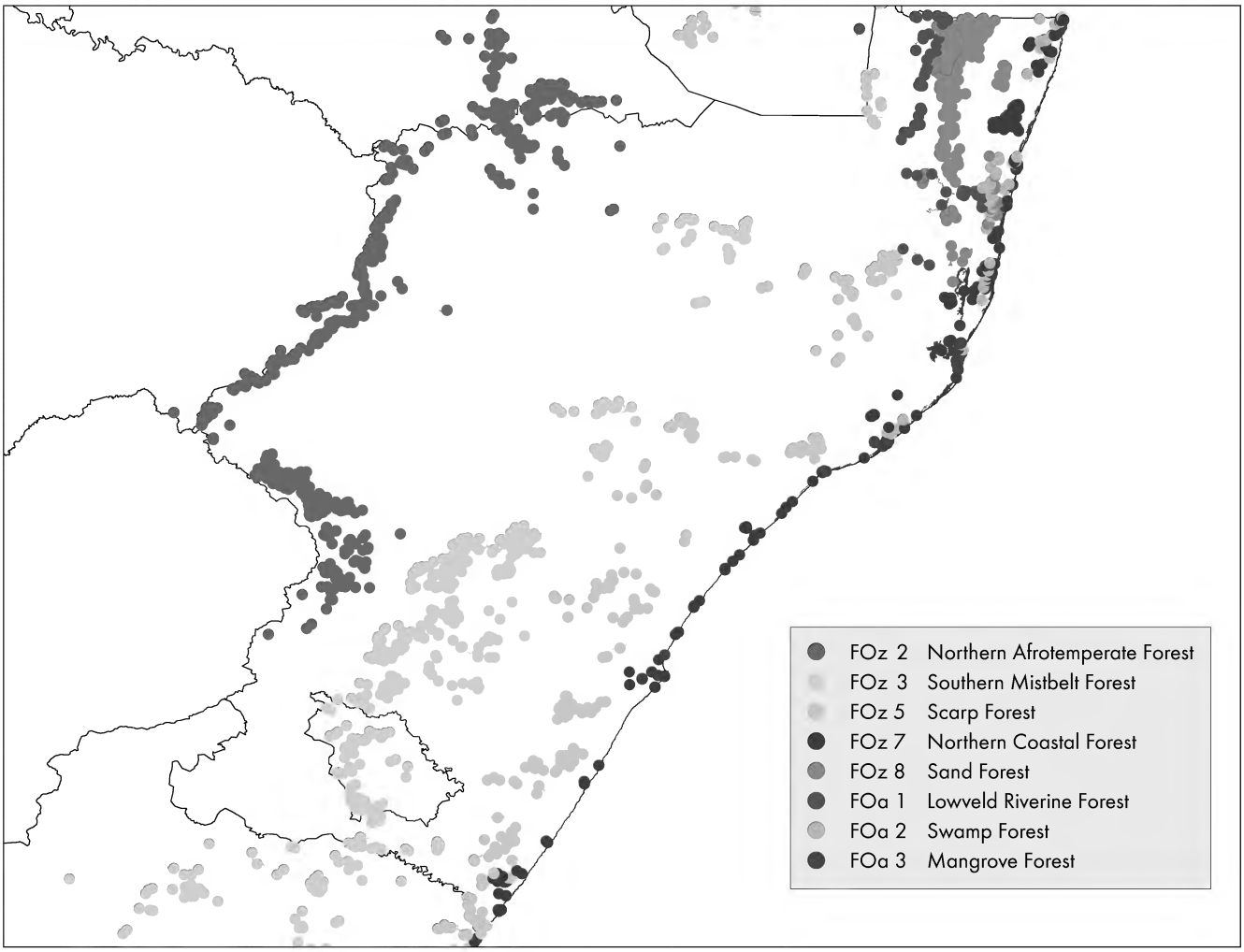


Figure 12.3 Distribution of the mapped vegetation units of the indigenous forests in KwaZulu-Natal.

The marginal (albeit very interesting owing to high concentration of tropical elements and endemic species) group of dry forests (represented by two vegetation units: Sand Forest and Ironwood Dry Forest) occur imbedded within seasonally dry and hot types of Lowveld (Maputaland and northern Kruger National Park).

There are three clearly hydrologic-edaphic azonal forest types typical of habitats controlled by specific hydrological regimes:

- LowveldRiverine Forest (gallery forest that fringes rivers in subtropical regions of South Africa and neighbouring countries).
- Swamp Forest (forest showing evolutionary and ecological links to tropical swamp forests of central Africa).
- Mangrove Forest (specific intertidal forests of subtropical and tropical coasts, reaching the southernmost distribution along the Indian Ocean coast of South Africa).

At least 7% of the country is a potential habitat owing to the favourable combination of climate and substrate suitable for forest growth. Still, forests cover just more than 3 000 km^2 or 0.1% of the land surface of South Africa (Huntley 1984, Cooper 1985, Rutherford & Westfall 1986, Anonymous 1987, Geldenhuys 2000a). This estimate varies depending on the criteria (minimum forest size mapped of 50 ha, 30 ha or 1 ha) and mapping method (use of satellite imagery or aerial photographs).

2. Current Biogeographic Patterns

In very general terms, the zonal forests in South Africa show floristic and palaeo-biogeographic links to two main African forest zones (Chapman & White 1970, White 1983, Timberlake & Shaw 1994), namely the afrotemperate forests and the coastal forests. The former is part of the Afromontane Region which also occurs outside South Africa further north in Zimbabwe, Malawi and along the East African mountain ranges, reaching as far north as Ethiopia and westwards to Cameroon and northern Angola. The coastal forests form part of the Tongaland-Pondoland Regional Mosaic with some forest elements shared with the adjacent Zanzibar-Inhambane Regional Mosaic (*sensu* White 1983). The former region has also recently been recognised as a Centre of Endemism (Van Wyk & Smith 2001), although one should reconsider joining Maputaland and Pondoland into one Centre because of the different geological and evolutionary ages of the two regions and their floras.

Taxa shared between forests show at least three patterns (Geldenhuys 1992a). Firstly, forest patches share many more of their species with neighbouring forest patches to their north and east than with those occurring to their south and west. This indicates the erosion of species diversity from the two tropical source areas—both mountains and coastal regions of East Africa—towards the South African distribution area of afrotemperate as well as subtropical forests (McKenzie 1978, Tinley 1985, Cawe 1986, Geldenhuys 1992b). For example, 206 of the 470 species found in the southern Cape forests (consider-

ing all growth forms) reach their geographical distribution limit here (Geldenhuys 1992b). Of these, 158 species reached their western limit and only 23 species reached their eastern limit in the area of the southern Cape forests. Secondly, forests share many more species with their nearest neighbouring forests than with forests further away. Thirdly, the afrotemperate forests (including those occurring in mountains close to the coast in the southwest of the country) share relatively fewer species with the forests of the subtropical coastal areas (Geldenhuys 1992a). Canopy trees and ferns have the lowest proportions of unique species, whereas these proportions are >40% for the shrubs, geophytes and forbs.

Reconstruction of the relic temperate flora of the small, isolated forests of the inland mountains of the southern Cape showed the changes in species composition that may have happened as a result of forest contraction and expansion due to landscape and climatic changes (Geldenhuys 1997a). The less isolated forests had been enriched from the large forest complex on the coast along specific migration routes and during specific waves of forest expansion. The distribution ranges of taxa of the southern Cape forests were used to establish generalised tracks of the flora in order to test hypotheses about the speciation and development of the forest floras (Geldenhuys 1994a). The results indicated that the ecological characteristics of species of each geographical species group reflected the environmental conditions and disturbance regimes that prevailed in each source area. The southern Cape forest flora was therefore considered to be composed of the following elements:

- Species adapted to a narrow, cool, humid afromontane area.
- Species of a transition zone between the montane zone and the humid, warm, subtropical coastal areas.
- Species adapted to more frequent and extreme droughts and drier conditions of the lowlands between the coast and mountains.
- Species adapted to the southern temperate cool, moist mountain areas.
- Species adapted to frequent grassland and shrubland fires on the forest margin.
- Local endemic species.

The present patterns of composition of the different forests (within either afrotemperate or coastal regions) suggest that their high degree of similarity may have been established before major fragmentation of the forests since the late Miocene—the time period which experienced increasing aridity (Geldenhuys 1992a). During this period of fragmentation, forests and forest biota survived in areas now considered as dispersal corridors. The number of dispersal corridors (mountain chains, escarpments, river valleys, coastal dune systems) meeting in a particular forest is probably one of the strongest variables determining the number of woody plants in a forest (Geldenhuys 1992a, 1997a).

3. Diversity Patterns

Geldenhuys (1992a) listed 1 438 plant species that had been recorded for 14 forests or forest complexes representing the geographical range of the mixed evergreen forests in South Africa. These included 155 families and 661 genera. The forests covered only 0.08% of the area and 7.1% of the vascular species, but had a relatively rich 0.58 species per km^2. Gibbs Russell (1987) indicated a ratio of 0.0079 plant species per km^2 overall for southern Africa, with 20 227 indigenous vascular taxa. Only fynbos exceeded the forest value with 1.36 species per km^2 (7 316 species). The third richest biome was grassland with 0.25 species per km^2 (3 788 species).

Plant species richness remains relatively constant along the tropical-temperate gradient of southern Africa, except for the southwestern extreme (Geldenhuys & MacDevette 1989, Geldenhuys 1992a). KwaZulu-Natal Coastal Forests and Pondoland Scarp Forests with a large proportion of endemic plants (Van Wyk & Smith 2001) have the highest number of woody species (254 and 338 species respectively). The Western Cape Afrotemperate Forests (from the Cape Peninsula to Swellendam) and the Drakensberg Montane Forests have the lowest number (48 and 78 species respectively). The number of both woody and herbaceous species of isolated forests and forest complexes increases with area of the forest (Geldenhuys 1992a). However, woody species richness is more strongly correlated with the proximity to other forests and the number of available dispersal corridors (mountain range, escarpment, river, coastal dune system).

The ratio of woody to herbaceous plant species varies greatly between individual forests (Geldenhuys 1992a). In general, coastal forests have a ratio in excess of 60%, whereas in montane forests the ratio varies between 39% and 53%.

Species richness varies more within a forest than between forests (Geldenhuys & MacDevette 1989). Montane forests, in general, have fewer species than lowland, coastal and dune forests, both in KwaZulu-Natal and the southern Cape. Furthermore, drier (or warmer?) forests are richer in species than wetter (or cooler?) forests. The different growth forms also show clear patterns amongst the different forest types. Species turnover of woody plants from montane to lowland forests increases more sharply than for herbaceous plants. Fern species richness experiences decline, and richness of vines, graminoids, geophytes and forbs increases from the montane to the coastal forests. The species richness of epiphytes is the highest in less disturbed and mature forests, especially in the mistbelt and subtropical forests.

4. Palaeo-ecological Patterns: Role of Climate and Fire

The remarkable variability of extant forests in southern Africa and their generally patchy (archipelago-like) dispersal over landscapes of several biomes are indicative of their relictual character. We discuss the role of two major probable agents that shaped the current and past forest patterns—climate and fire.

Geldenhuys (1994b) suggested that not only environmental factors (rainfall and substrate) determine the potential limits of forest distribution but that actual pattern of forests and their boundary shapes are to a large extent (particularly in hilly and mountainous areas) determined by the fire pattern. This pattern, in turn, is determined by the interaction between the prevailing winds during dry periods and terrain physiography. Gusty, hot, desiccating northwesterly föhn-like berg winds are common during autumn and winter (Tyson 1964, 1986). Berg wind direction is locally changed by barriers, such as the mountain ridges to the windward (northern) side of the forests. The wind direction is channelled through valleys running from the mountains, and its flow direction is determined by the position and form of the barriers (see Figure 12.4). Lightning and human-induced fires (Deacon et al. 1983) are exacerbated by the berg winds. The fires burn with higher frequency in zones in the landscape where forest is absent (fire pathway), fragmenting the forests along the fire pathways. Forest persists in the

topographic or wind shadow areas (also called fire refugia).

The borders between forests and surrounding fire-prone ecosystems (FPE; *sensu* Bond et al. 2003b), including Fynbos, Grassland and Savanna, are characteristically sharp. Geldenhuys' (1994b) hypothesis addresses this phenomenon convincingly in regions of frequent berg winds and under current climatic conditions (Figure 12.4 and 12.5). Persistence of the large number of forest patches scattered over vast areas of southern Africa and the existence of sharp forest limits outside the regions of berg-wind influence demand additional, alternative explanations. Increased inflamability due to long-lasting (unusual) droughts and unnatural high-frequency of man-made fires in coastal grasslands may alter forest limits (Figure 12.6). Sharp change in substrate properties, such as observed on the border between boulder screes on steep slopes in deep kloofs (supporting afrotemperate forest) and the surrounding fire-driven fynbos (Figure 12.7), may be seen as another important factor for survival of forest patches in a FPE landscape.

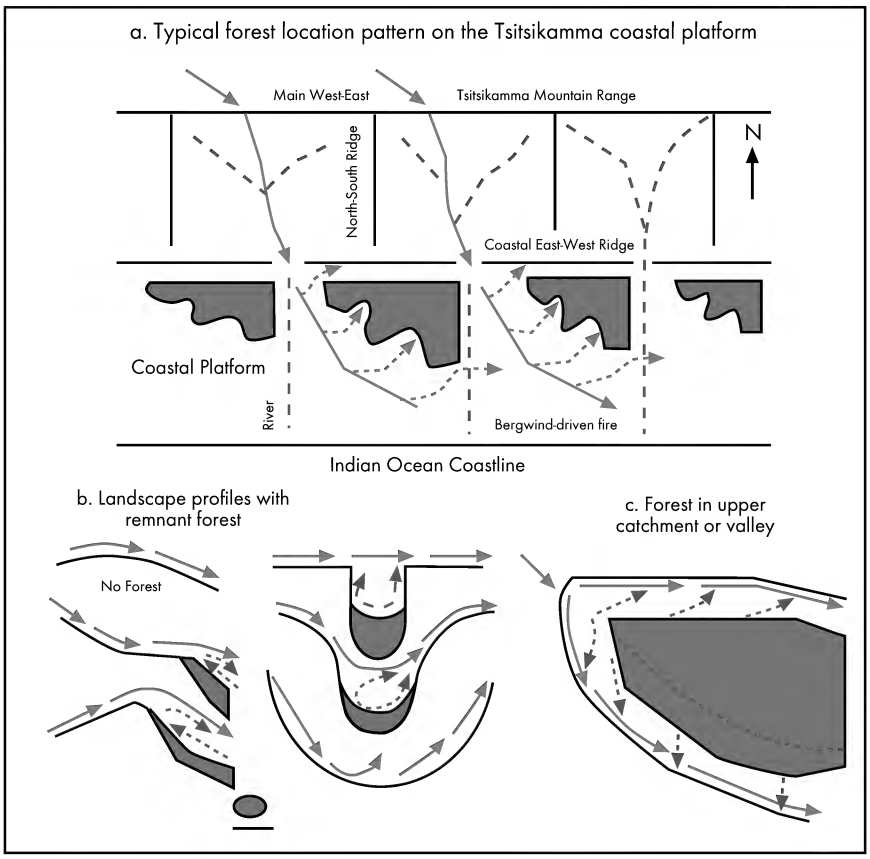


Figure 12.4 Schematic view of hypothetical airflow across and around topographic barriers to show the persistence of forest in wind-shadow areas in relation to wind-driven fires (adapted from Geldenhuys 1994a; courtesy of Blackwell Science Publishing).

Fire does not normally play a role in ecosystem dynamics of forest patches, except at the fringes (Bailey et al. 1999). However, Geldenhuys (1993e) collected charcoal from the litter and feeding root zone of many seemingly mature forest stands throughout the southern Cape. The charcoal resulted from fires caused by lightning (Geldenhuys et al. 1994), spotting during berg winds or by honey collectors. In principle, the South African forests (in particular the afrotemperate ones) as we know them today are non-flamable by nature. A study by Van Wilgen et al. (1990) has shown that the reasons for fire-resistance of forests can also be found in vegetation structure (spatial compartmenting of fuel) and physico-chemical properties of the fuel with high moisture and low fat content in the leaves. For various causes of and response of forests and species to fire inside forests, we refer to papers by Edwards (1984), Granger (1984), Pammenter et al. (1985), Lübbe (1990a) and Geldenhuys et al. (2002).

From a palaeo-ecological perspective, fire must have played a major role in shaping the extent of forests in our region since the formation of the fire-prone ecosystems (late Miocene-Pliocene; see chapters on Grassland and Savanna in this book). Subtropical and warm-temperate evergreen forests covered the largest part of Africa until the Great Escarpment was formed and separated the moist coastal belt from the arid interior (Deacon 1983, Deacon et al. 1983). Increasing aridity (combined with prolonged dry seasons) developed, and increased fire frequency contributed to the expansion of fire-adapted woodlands, shrublands and grasslands. The relictual nature of the forests within the grasslands and woodlands has been attributed to the destructive activities of man during the relatively recent past, i.e. over the last 100 to 300 years (e.g. Acocks 1953, White 1983). However, as argued by Deacon et al. (1983) and Meadows & Linder (1989, 1993), patterns of forest distribution were to a far greater extent determined by climatic (see Eeley et al. 1999) and landscape changes.

C. J. Geldenhuys

Figure 12.5 Patches of Drakensberg montane forests (FOz 2 Northern Afrotemperate Forest) in fire-protected kloofs in the Cathedral Peak area (uKhahlamba-Drakensberg Park, KwaZulu-Natal). The fire-exposed ridges are devoid of forest (see also Figure 12.4).

Scholtz (1986) demonstrated from palynological and charcoal studies that large climatic changes occurred in the south-

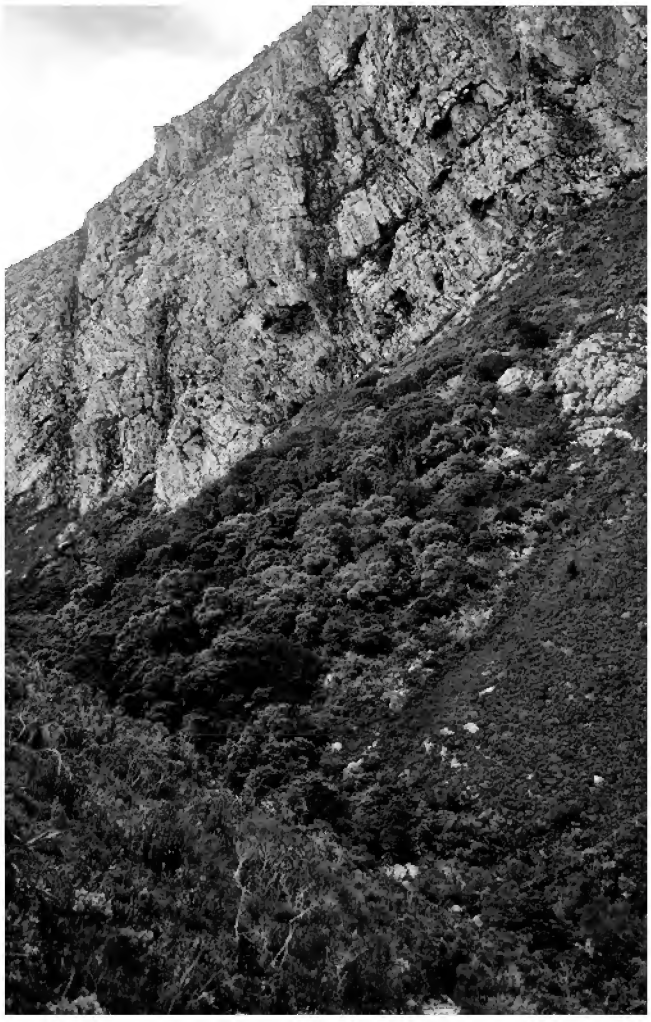
W.S. Matthews

Figure 12.6 Scorched edges of a dune forest (FOz 7 Northern Coastal Forest) neighbouring onto coastal grassland in Maputaland (northeastern KwaZulu-Natal).

ern Cape over the last 60 000 years. Since the cold and dry Last Glacial Maximum, the most mesic period (with forest expansion) was between 14 000 and 12 000 BP. This was followed by a hot, dry period (with forest regression) until the climatic optimum period fostered forest spread during the period 4 000 to 2 500 BP. Another period of warm, dry summers followed, accompanied by forest regression. However, the climate since about 1 400 BP is considered to have been similar to the present and supported another boost of the forest spread.

Hypotheses addressing the past and present distribution of forests (in particular the age of forests and their persistence on a site) must consider the origins and dynamics of the surrounding FPEs. A study of West et al. (2000), using oil-carbon isotope methods, revealed that C_4 plants (hence grasslands) earlier dominated the site that is today covered by Hluhluwe Forest—a member of the endemic-rich vegetation unit FOz 5 Scarp Forest. Incidentally, the Hluhluwe Forest itself houses *Albizia suluensis*, a very restricted local endemic. West et al.'s study concluded that grasslands were precursors to the forest vegetation in the region because of the observed shift from a also C_3- to C_4-dominated ecosystem with increasing soil depth. This fact, however, does not preclude a possibility of existence of this forest on the site in pre-Pliocene times. Its extent might have undergone reduction (or even obliteration in the study site). The Hluhluwe Forest could have regenerated from close-by patches, still leaving a C_3–C_4 transition signal behind. Simulation studies (Bond et al. 2003a, b) predicted a shift from C_4- to C_3-ecosystems, due to increase of woody biomass, under exclusion of fire. Considering the long-term dynamics of forests (and FPEs surrounding them), a new element of ecological thinking appears —the interaction of CO_2 ambient concentration and fire (Bond et al. 2003a). Paleoclimatology presumes that during LGM (21 000 to 18 000 ya) and implicitly during all glacial maxima of the other 20+ glaciation cycles during the Pleistocene (and possibly beyond into Pliocene), the forest cover was sparse. During the LGM low CO_2 levels (180 ppm) have promoted C_4-dominated grasslands. A simulation study by Bond et al. (2003b) argues, that by current (human-forced) levels of CO_2 of 360 ppm, the grassland ecosystems with precipitation above 650 mm would develop towards fire-sensitive forest, if fire was excluded. Also the mesic fynbos would then turn into forest under the simulated conditions. Experiments addressing success of establishment of forest precursors in fynbos (Manders 1990, Manders & Richardson 1992) lend this idea strong support. Rebelo et al. (see Chapter on Fynbos in this book: FFg 3 Peninsula Granite Fynbos) argue that changes in fire-management allowed forest to take over much of the area formerly covered with granite fynbos over a short period of only several decades. In the Soutpansberg, and along the Northern Escarpment, the exclusion of fire changed some grasslands to forests through woodlands serving as an intermediary step (Geldenhuys & Venter 2002).

Despite mounting evidence for the role of climate and fire in shaping the current patterns of forest cover, the influence of man cannot be denied. Climatically favourable Holocene and human-enforced increases of temperature result in expansion of the forest cover. Still some potentially forest-rich regions (see Chapter on Indian Ocean Coastal Belt in this book) show only very fragmented and scanty forest cover. We argue that these regions, comprising mainly the coastal belts of KwaZulu-Natal and the north-eastern Eastern Cape have experienced heavy forest clearing in the past. The Iron Age farmers migrating southwards along the



L. Mucina

Figure 12.7 Patch of afrotemperate forests on scree (Table Mountain Group sandstone) in Leopard's Kloof in the Harold Porter National Botanical Garden (Betty's Bay, Western Cape).

broad coastal belt settled in high density in preferred sites at least over the last 1400 years. Forest and scrub forest have been continuously cleared for pastures and exploited for timber, plant foods and medicines during this period (Feely 1980, 1987), but also recovered in many places in the same areas (Von Maltitz et al. 1996).

5. Ecology

5.1 Climate

Forest is limited to regions with high water availability. This is mostly determined by high rainfall, though riverine and kloof forests exist outside the normal rainfall envelopes associated with forests—here the groundwater, flood water and shelter phenomenon (deep gorges with low solar irradiation, hence lower evaporation and evapo-transpiration) play a role. Hence, the water availability to forest vegetation is a function of amount of precipitation (rainfall and mist), evapo-transpiration, availability of groundwater and, in addition, soil structure and seasonality of precipitation.

Forest persists in areas with mean annual rainfall >525 mm with strong winter rainfall and >725 mm with strong summer rainfall (Rutherford & Westfall 1986, Geldenhuys 1991). Rutherford & Westfall (1986) have suggested that a summer aridity index may be a better predictor of forest distribution than rainfall per se. They have shown that forests grow under lower rainfall conditions in winter-rainfall areas than in summer-rainfall areas. The basic climatic characteristics of the forest vegetation units are depicted in the climate diagrams featured in Figure 12.8.

Mist precipitation along the Great Escarpment and some exposed mountain ranges supplements the rainfall considerably. Forests are, however, also found along rivers and in protected kloofs (gorges) in areas of lower rainfall (Von Maltitz et al. 2003). In the drier inland areas, mountains provide important sites for development of forest, e.g. the southern slopes of the Soutpansberg (Geldenhuys & Murray 1993) and sheltered valleys in the southwestern Cape (McKenzie 1978, Masson 1990, Geldenhuys 1997a).

Most areas covered in forest are linked to orographic precipitation. These mountainous areas show steep gradients in precipitation and localised rain shadows. Spatial patterns of total precipitation do not show a clear correlation with forest type distribution. Most afforested areas of the country show local gradients in rainfall. The following conclusions were drawn from an analysis of rainfall envelopes for the indigenous forests:

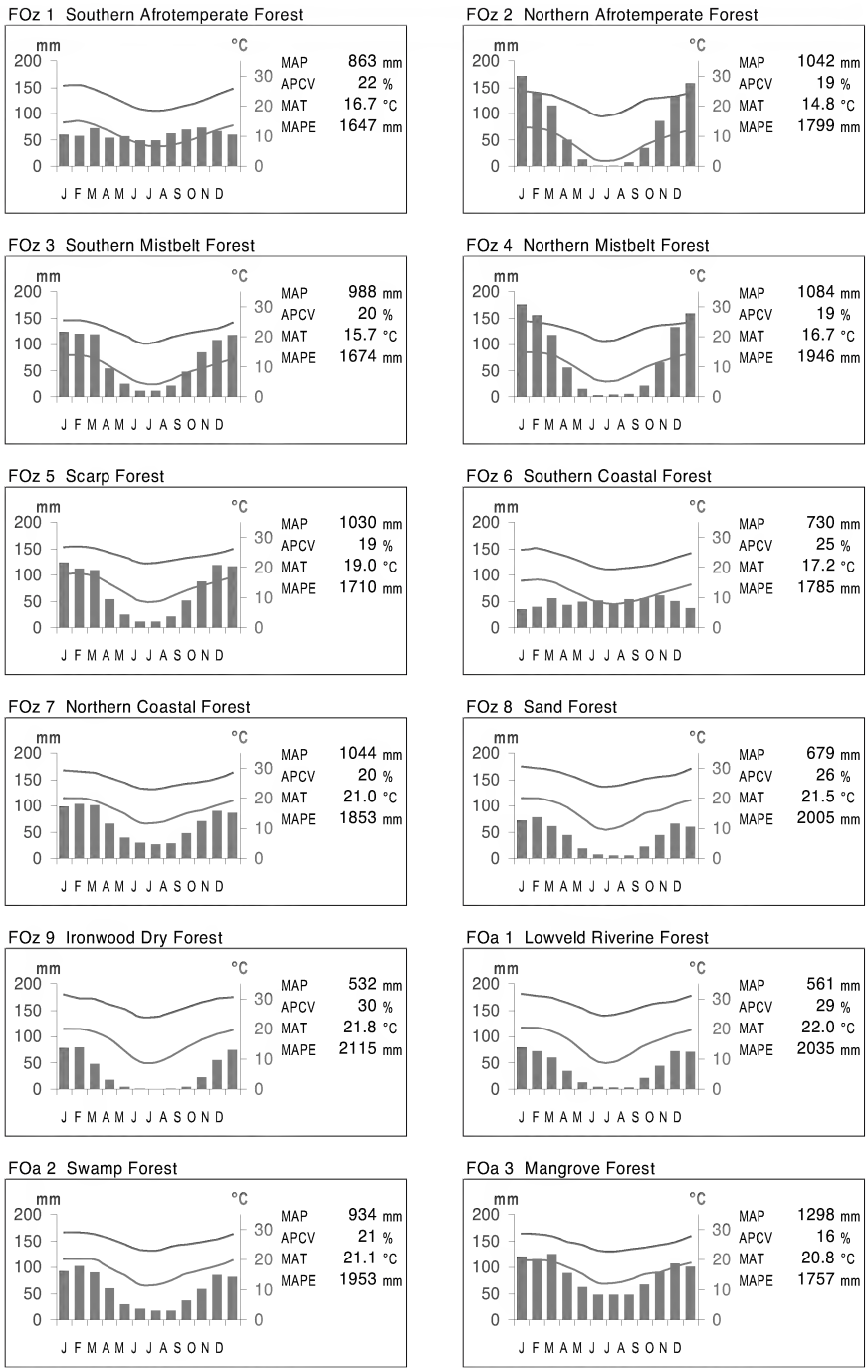


Figure 12.8 Climate diagrams of afrotemperate, subtropical and azonal forest units. Blue bars show the median monthly precipitation. The upper and lower red lines show the mean daily maximum and minimum temperature respectively. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MAPE: Mean Annual Potential Evaporation.

- Azonal types, and especially riverine forest, occur in areas of lower rainfall than are typical for forests.
- The areas of highest rainfall are found in the Mpumalanga and Soutpansberg areas.
- The Alexandria (Albany) forests have lower rainfall than most forest types.
- The southern Cape forests have a mix of rainfall, with some areas receiving low rainfall (Geldenhuys 1991 indicated a range from 500 mm near Great Brak River to 1 200 mm in Jonkersberg, Diepwalle and Storms River).

Two discernible gradients exist in seasonality of precipitation. There is a trend from west to east following the coastline from the Western Cape coast with winter rainfall to all-year rainfall in the Knysna region. Most of the remaining coast to the east has predominantly summer rainfall, though the northern KwaZulu-Natal coast also receives rainfall all year. From Port Elizabeth eastwards there is a gradient from the coast inland of increasingly greater summer dominance of rainfall.

A number of factors influence temperature within forests. Temperature decreases with both latitude and altitude. Proximity to the coast has a moderating influence on temperature and tends to reduce the range in temperature extremes. Maximum temperature is most extreme on the KwaZulu-Natal north coast where mean maximums for the hottest month are in the region of 30°C and mean annual temperature is 22°C. Temperature decreases southwestwards along the coast to a mean maximum of 25°C for the hottest month in the afrotemperate forests of the Knysna area. Inland areas tend to be cooler, especially in the mistbelt and high mountains of KwaZulu-Natal. The inland Eastern Cape region has higher maximum temperatures than other inland forests.

The coastal influence moderates minimum temperature in the coastal region. Along the coast there is a decrease in temperature from the northern Zululand coast through to the George-Knysna area. Inland minimum temperatures decline rapidly from the coast towards the mountains as altitude increases. There is also a discernible decrease in temperature with latitude.

Persistence and recovery of forests are also linked to microclimate created by the forest patches themselves. A mixed evergreen forest is a layered community and always has a continuous tree layer, with or without shrub and/or herbaceous layers (Geldenhuys et al. 1988a). The layering and the closed forest canopy buffer the outer macroclimate to create a more equable internal microclimate (Geldenhuys 1993a). In relation to conditions above the canopy, the temperature in the shrub layer is lower, the humidity is higher and the wind speed is considerably lower to almost nonexistent, even during berg wind conditions. Large gaps created in the canopy during road construction or careless timber harvesting have two major effects on the plants growing in and around such gaps. Below-canopy plants are exposed to the more extreme conditions prevailing outside the canopy. Many of them cannot adapt to the changed conditions, and die. Wind blowing over the relatively smooth, undulating forest canopy becomes turbulent within the gap and uproots the trees on the side of the gap from which the wind blows (Geldenhuys et al. 1988b).

Vegetation of a natural forest edge has an effect on the microclimate of the forest interior similar to that of the closed forest canopy. A natural forest edge consists of plants of various growth forms and sizes that close the gaps between the mature trees. It usually forms what is known as a soft edge, which gradually decreases in height and increases in foliage density away from the mature forest. This transitional area, or ecotone, also has a higher biodiversity than either the forest or the outside vegetation, because it includes elements of both. Creation of a hard forest edge, such as during removal of the forest edge vegetation or cutting of a clearing in the forest, exposes the forest interior to penetration by the hot, dry and gusty winds, and even fires, to the detriment of the less hardy plant species that grow there.

5.2 Geology and Soils

The substrates supporting forests include a wide range of geological formations: quartzitic sandstone, mudstone, shale, schist, Enon conglomerate, dolerites, dolomite, granite-gneiss and aeolian sands (Geldenhuys 2000a). The derived soils vary in depth, water-holding capacity and nutrient status.

The high rainfall in areas supporting forests has major effects on forest soils. It causes waterlogged conditions in clayey soils and leaches the soluble nutrients deeper into the soil. The result is that the trees develop very shallow root systems. In the southern Cape forests, in general, the root system of a tree has a maximum depth immediately beneath the bole and decreases further away from the tree where the roots are confined to the top 30 cm of the soil (Kotze & Geldenhuys 1992). Large individual trees of *Afrocarpus falcatus* have roots of more than 20 cm in diameter appearing above the soil surface and extending horizontally for distances in excess of 40 m away from the bole. A dense mat of fine, feeder roots concentrates in the upper 10 cm of the soil. The waterlogged conditions inhibit penetration of roots deeper into the soil, where they would suffocate from lack of oxygen. The main function of the feeder roots is to absorb nutrients from decomposing litter in the upper part of the soil profile. Disturbance of the root and litter layers will have significant negative effects on forest nutrition, and this will, in turn, adversely affect forest regeneration and recovery. The trees are also particularly sensitive to poor soil aeration caused by standing water resulting from disturbance of the natural drainage patterns and from soil compaction (Geldenhuys et al. 1988b, Lübbe & Mostert 1991). Naturally, the trees, shrubs and many herbs of the riverine, swamp and mangrove forests have developed a number of adaptations to cope with anaerobic conditions in waterlogged soils.

6. Forest Dynamics

Forest stand dynamics are determined by a number of important processes inside the forests, such as natural disturbance and gap dynamics, litter fall and a closed nutrient cycling, characteristic fruit and seed types and associated regeneration processes, and plant-animal interactions.

6.1 Gap Dynamics

The forest interior is subject to regular small-scale disturbances causing gaps of 0.005 to 0.5 ha (Geldenhuys & Maliepaard 1983, Midgley et al. 1995). Lightning may cause a fire or merely kill a small group of trees (Geldenhuys et al. 1994). Some trees, such as *Ocotea bullata*, can recover from such strikes by resprouting, whereas others (e.g. *Rapanea melanophloeos*) can be easily killed. Hail events occur very infrequently, but still they can cause major damage by defoliation of whole stands. Winds cause the breakage of large branches or occasionally uproot a single tree, or at the most a small group of trees. Large windfalls occur very infrequently in the southern Cape and other forests along the escarpment. In northern KwaZulu-Natal tropical cyclones occasionally flatten large parts of the coastal and riverine forests. However, most trees die standing and singly from old age or some form of disease or stress (Geldenhuys & Maliepaard 1983, Midgley et al. 1995). Van Daalen & Shugart (1989) applied an individual-tree gap model aimed at simulating succession dynamics on a site in the Outeniqua Forest (near Knysna) using demographic parameters for 28 woody plant species.

Severe droughts affect the forests from time to time. In 1983 the leaves of most evergreen trees in some Eastern Cape forests died on the trees (Geldenhuys 1993b). The leaves of the evergreen *Buxus macowanii* remained green throughout the

drought, but many plants died shortly afterwards when they were totally defoliated by larvae of a moth species, which appeared in large numbers after the first rains.

6.2 Litter Fall and Nutrient Cycling

The high nutrient content in the surface layers of the soil is maintained through the fall of litter—leaves, twigs, bark, flowers and fruit—as well as through the death of forest microbes and animals (Geldenhuys & Theron 1994). Contrary to the general (perhaps eurocentric) perception that leaves fall in autumn, leaf fall in the South African indigenous forests occurs throughout the year, but with a definite peak in midsummer (December and January). During this time the rainfall is high (except in the west), but the trees experience a physiological drought because of the high temperatures and associated high loss of water due to transpiration. The total litter fall in forests in the southern Cape amounts to 3 000–4 500 kg. $ha^{-1}.yr^{-1}$ (Geldenhuys & Theron 1994), but it may reach values up to 10 000 $kg.ha^{-1}.yr^{-1}$ in the high-rainfall areas of the Limpopo Province (Geldenhuys et al. 1984). The total amount of litter increases with increasing total mass of living material (biomass) of the forest, which is well correlated with rainfall. The litter, with the leaf component forming about 80%, decomposes relatively quickly. However, the decomposition in the warm-temperate forests proceeds at a much slower pace than in warm, moist tropical rainforests. The rate of decomposition of the litter is about two years for a moist forest, and four years for a dry forest, resulting in a gradual build-up of litter on the forest floor (Geldenhuys & Theron 1994).

Forests can also grow on nutrient-poor or shallow soils, provided that the moisture is sufficient and disturbance is minimised, so that the nutrient cycle can develop. It is a slow process and one that requires the recovery and increase of the nutrient status in the upper layers of the soil.

6.3 Dispersal Syndromes and Animal-plant Interactions

The suite of dispersal syndromes in the southern Cape indigenous forests are considered (Geldenhuys 1993c) to be similar to those of the closed, mixed tropical-subtropical forest as described by Hall & Swaine (1981). They include:

- 34% Species with small, dry seeds dispersed by gravity or ballistic mechanisms.
- 24% Species with small seeds either from fleshy fruits or with a fleshy aril from drier fruits, dispersed by frugivores.
- 18% Species with spores or dust-like seed for dispersal by wind.
- 8% Species with fleshy fruits with large seeds, dispersed by larger frugivores.
- 8% Species with small seed with a pappus or wool for wind dispersal.
- 4% Species with larger dry seeds from capsules, cones or nuts, dispersed by mechanical means.
- 3% Species with seed with attachments for accidental dispersal by mammals.

The representation of propagule type also varies across growth forms (Phillips 1931, Geldenhuys 1993c). Fleshy propagules, especially of small size, predominate in tree species. Large fleshy propagules are more important in canopy than in sub-canopy trees. Large dry propagules are more common than small dry ones in both canopy and sub-canopy trees. Very few tree species have true wind-dispersed seeds. A few trees have very small seeds that can drift in the wind over short distances. Woody shrubs usually have small, fleshy propagules and soft shrubs mostly small, dry ones. Lianas have either fleshy (64%) or wind-dispersed (36%) propagules, whereas vines have dry (64%), mostly wind-dispersed (53%) propagules. The other categories occur in the geophytes, graminoids, epiphytes, ferns and other forbs. Fruit type and seed dispersal agent are important in the seedling germination and population demography of many forest species (Geldenhuys 1996a).

Forests are home to many animal species—they use them for shelter, breeding and forage. Animals act both as disturbance and regeneration agents. Most of the mammals and a large proportion of the birds found in South African forests are not confined to the forest habitat and have wide distribution ranges (Geldenhuys & MacDevette 1989). Many of the forest-dependent birds migrate to forests at lower altitudes during winter.

Bird species richness is relatively low in forest areas and shows a decline from north to south like plant species do (Koen & Crowe 1987). For example, moving southwards from the Eastern Cape, 54 species have been recorded in Dwesa Forest, 43 in Alexandria Forest, 35 in Diepwalle Forest near Knysna, and only 15 in forest patches of the Cape Peninsula (Cody 1983).

Forest mammals generally occur solitarily or in small groups, are shy and many are nocturnal. Mammals are particularly important in forest dynamics in browsing of young plants and coppice re-growth (Lübbe 1990b), in seed predation (Geldenhuys 1993d, Koen 1991) and seed dispersal (Koen 1983, Geldenhuys 1993d, 1996a). Birds are important in pollination and seed dispersal (Koen 1988, 1992, Geldenhuys 1996a).

7. Status of Indigenous Forests of South Africa

Ownership determines the type and quality of forest management and possible impacts on the vegetation (Phillips 1963, Cooper 1985, Cawe 1986, McKenzie 1988, Geldenhuys 1991, Cooper & Swart 1992). Most of the forests are surrounded by areas of high population density (Geldenhuys 1999a). Some forests occur in areas surrounded by developed affluent societies. In such areas, the people strive to satisfy higher-order needs, such as high-quality furniture and crafts, recreation and ecotourism, and biodiversity conservation. In general the forests expand, with a small impact from development (roads, power lines, dams, housing complexes). Other forests occur in areas surrounded by poor developing rural communities. In such areas, traditional subsistence practices are used to satisfy the livelihood needs, such as building material, fuel wood, food and medicine, and other household goods. The actions are poverty-driven because people lack alternative income-generating activities. Such activities often lead to forest degradation. The challenge is to move the living standards of the rural poor towards higher income-generating levels of society.

The national and provincial governments and statutory bodies manage and control a very large proportion of the forests (and the largest forests), and only a small portion is privately owned or on communal land (Cooper 1985, Geldenhuys & MacDevette 1989, Geldenhuys 1991). Conserved forests in South Africa range from forests in private and tribal ownership that are in good condition, to forests in conservancies and natural heritage sites, through to forests in nature reserves and

wilderness areas proclaimed under the Forest Act. There are many forests outside the proclaimed areas that are well conserved but with insecure conservation status. Geldenhuys & MacDevette (1989) defined conserved forests as those in the custody of government authorities, including the National Parks Board (currently South African National Parks) and city councils. The forest types and forest complexes in southern Africa are generally well conserved (Geldenhuys & MacDevette 1989, Von Maltitz et al. 2003). However, various sources still exert pressure on these forests (McKenzie 1988, Geldenhuys & MacDevette 1989, Von Maltitz et al. 2003):

- Growing human needs in rural tribal areas (uncontrolled use of forest resources for construction, crafts and traditional medicine, and forest clearing).
- High-intensity farming interests (causing the clearing of scrub forest and riverine forest for agriculture).
- Economic pressures (causing uncontrolled exploitation, grazing and burning of forests on farms).
- Mining of forested dunes along the coast.
- Development of infrastructure (roads, power lines, dams), township and resort developments.

8. Threats to Indigenous Forests of South Africa

With the settlement of the Europeans in southern Africa since 1652, large-diameter trees of selected species were harvested for building and furniture timber and for railway sleepers (King 1938, 1941, Phillips 1963, McKenzie et al. 1977, Scheepers 1978, Cawe 1986). However, the forests of South Africa have played a role over a much longer period in the welfare of society that is disproportionately greater than their small extent and low potential for commercial exploitation. McKenzie (1988) recognised many direct uses and indirect values of the South African forests. A review showed that 365 of the 568 tree and shrub species recorded from 14 forest complexes throughout South Africa (Geldenhuys 1992a) were utilised for a wide range of direct uses (Table 12.2; Geldenhuys 1999a). A recent survey of 21 villages for forest resource accounting in the Eastern Cape Province (with many forests in poor rural areas) showed much informal commercial and subsistence use of the forests (Hassan & Haveman 1997). A total of 140 tree and shrub species were recorded, some more widely and generally used than others, but not all were indigenous species. The uses include a variety of poles (mainly for construction), firewood, crafts (from timber and non-timber species), binding and weaving, food sources (vegetables, fruits and bush meat), and traditional medicine (bark, roots and other sources). Poverty of rural people and their inability to afford alternative commodities cause a continuous use of products from the forests and increased forest clearing to grow crops to support their families.

Fuel wood represents the highest volume of forest products used by rural people (Basson 1987) and the resulting pressure is particularly severe where the forests are not surrounded by woodland, plantations or woodlots of introduced species (McKenzie 1988). *Acacia natalitia* (formerly included in *A. karroo*: see Coates Palgrave 2002), a pioneer species in many forest areas along the coast, is an important firewood species (Hassan & Haveman 1997, Van Eck et al. 1997). Climbers, leaves, leaf petioles and tree bark are sources of binding materials (Cunningham & Gwala 1986). Use of wood for building varies with building style and availability of materials, and a variety of species have been recorded (Johnson 1982, 1983, Cunningham 1985, McKenzie 1988, Van Eck et al. 1997, Obiri 2002, Obiri et al. 2002). Traditional medicines are important to rural communities for medical, psychosomatic and economic reasons (McKenzie 1988). Urbanisation of rural people has generated a local and countrywide multimillion Rand annual trade between rural source areas and urban markets and shops (Cunningham 1986, Williams et al. 1997, Mander 1998). This trade has increased the pressure on the forests in the rural areas and on specific species such as *Rapanea melanophloeos, Curtisia dentata, Prunus africana* and *Ocotea bullata* in the Umzimkhulu District in the Eastern Cape (Geldenhuys 2002, 2004).

Coastal Forests and Dune Forests experience significant current utilisation pressures with the potential to increase. These forests have more species bearing fleshy fruits (a primary source of vitamin C), whereas Sand Forest has the highest diversity of fruit-bearing species (Cunningham 1985, McKenzie 1988, Van Eck et al. 1997). Several home crafts are based on sources from the forest (McKenzie 1988). Various palms, reeds and climbers are used, mainly for baskets and mats, for example *Flagellaria guineensis* (Cawe & Ntloko 1997), and the pioneer tree *Millettia grandis* is used in woodcarving (Obiri & Lawes 1997). Around Port St Johns (Eastern Cape coast) people directly employed in craftwork earn an annual income of over US$0.2 million (Obiri & Lawes 1997). Fronds (leaves) of the fern *Rumohra adiantiformis* are used extensively in the florist trade, both locally and abroad. Since 1981 the development of the export market for the fern has developed into a lucrative local industry (Milton 1987a, b,

Table 12.2 Number of tree and shrub species in the South African forests that have been or are still used traditionally and/or commercially (Geldenhuys 1999a). C: Canopy trees; SC: Sub-canopy trees; S: Shrubs.

Category	Use	C	SC	S
Timber	Furniture	43	13	-
	Construction	40	26	6
	Poles	15	22	6
	Fuelwood	18	25	4
	Ornamental	45	42	18
Traditional medicine (by plant part used)	Leaves	10	22	15
	Fruit	2	5	2
	Bark	34	34	4
	Roots	10	17	13
	Other	18	16	13
Food (by plant part used)	Leaves	-	3	3
	Fruit	29	38	29
	Roots	2	-	2
	Other	2	2	-
Crafts (from other than timber)	Basket	-	2	3
	Weaving	1	-	-
	Binding	2	7	6
	Other (including dyes)	6	12	2
Other uses	Horticulture	83	100	93
	Floristic	-	2	-
	Other	15	10	12
Total in forests		**109**	**185**	**274**
Total used		**102**	**143**	**120**

Geldenhuys & Van der Merwe 1988, 1994, Geldenhuys 1994c). During 1994/1995, 2.2 million fronds were harvested from the forest over a total area of 15 000 ha and sold for a value of almost US$125 000.

9. Action: Conservation and Utilisation

The initial colonial timber exploitation and destruction of forests was followed by forest protection since 1939 and the development of sustainable forest management systems (King 1938, Phillips 1963, Geldenhuys 1980). Today timber and other minor but important forest products are utilised conservatively from ecologically suitable but small areas of State Forest. Two large forest complexes, the southern Cape and Amathole forests, are mainly state-controlled and managed under a formal multiple-use system, with close monitoring to ensure sustainable use (Phillips 1931, Laughton 1937, McKenzie 1988, Seydack et al. 1990, Geldenhuys 1994c, 1996b, Seydack 1995, Vermeulen 2000). Scientific and multiple-use management principles were developed in the southern Cape forests and are applied through five management classes (production 19.8%; protection 55.8%, nature reserves 23%, recreation 0.4% and research 1.1%) in order to sustain utilisation of forest products, recreation and conservation. Furniture timber is currently provided mainly from the relatively large southern Cape forests where this industry has an annual turnover of >15 million Rand and employs about 650 people, and from the Amathole forests. Today commercial plantations of pines, eucalypts and wattles, covering >1.4 million ha, provide in the structural timber needs of the region.

Commercial forestry plantations of pines, eucalypts, acacias and other species have been established in the grasslands and shrublands surrounding the forests, but rarely in areas cleared of evergreen forest. Interestingly enough, besides the obvious negative effect of establishment of forest plantations on biodiversity of grasslands and fynbos (see Chapter on Grassland in this book), there are also positive sides to such silviculture practices: the plantations aid the rehabilitation of the forests, and expansion in places, reduce pressure on the forests for timber, fibre and firewood needs, and protect forest margins against frequent fires (Geldenhuys et al. 1986). Commercial timber plantations currently cover an area of about 1 487 million ha, comprising 53.2% pines of various species, 39.2% eucalypts of various species and 7.6% acacias (mainly *Acacia mearnsii*) and other species (Forestry SA 2002). Several good indigenous timber species can grow fast outside the forest if planted in suitable sites and managed appropriately (Lübbe & Geldenhuys 1991, Geldenhuys & Von dem Bussche 1997), and several of these species establish naturally under nurse stands of, for example, pines, eucalypts and acacias (Van Wyk et al. 1995, Geldenhuys 1996c, 1997b, Geldenhuys & Delvaux 2002).

The establishment of pure stands of indigenous tree species through planting was practised for many years, but this proved to be a very expensive process. A more acceptable and cost-effective approach was developed. Recent studies show that tree plantings catalyse or nurse the establishment of natural forest species to restore forest biodiversity and productivity (Geldenhuys et al. 1986, Parrotta 1995, Geldenhuys 1996c, 1997b, Parrotta et al. 1997). It is based on the concept that if fire is controlled in the landscape (urban development, crop production, commercial plantations), the areas in the former fire pathways (Figure 12.4) grow back to trees: firstly by alien invader species. They are intolerant of shade, cannot establish under their own canopy, but shade-tolerant forest species become established in the understorey (Geldenhuys 1994d, 1996c, 1997b, Geldenhuys & Delvaux 2002).

Careful manipulation of the invader stand through selective thinning where forest species start to establish, facilitates stronger growth of the established indigenous species and establishment of more species (Geldenhuys et al. 1986). Eventually the invader plant stand can be converted to re-growth forest. Similarly, plantation stands can be converted to forest (Van Wyk et al. 1995). This can also be done with natural stands of indigenous forest pioneer species such as *Acacia karroo* (as well as *Acacia kosiensis* and *A. natalitia,* formerly included within *A. karroo*; see Coates Palgrave 2002), *Trema orientalis*, *Virgilia divaricata* and other useful, fast-growing indigenous tree species such as *Afrocarpus falcatus, Millettia grandis, Ptaeroxylon obliquum, Prunus africana, Rapanea melanophloeos* etc. (Van Wyk et al. 1995, Geldenhuys & Delvaux 2002). Nurse stands of indigenous species can also be planted to develop useful, mixed forest stands in degraded forest gaps or forest margins (but outside the fire zones) to restore forest (Geldenhuys & Von dem Bussche 1997, Geldenhuys & Delvaux 2002).

Facilitation of forest re-establishment and recovery, using stands of planted trees, provides the basis for combining forest rehabilitation and production of the plants used by rural communities for their daily livelihood (Geldenhuys 1999b). Selected, traditionally used forest species grow faster in mixed-species stands, add value to products harvested from the planted stands through small businesses, reduce the pressure on forests through socio-economic upliftment of poor rural communities, and restore forest. Restoration actions are successful only if they are economically viable or if they provide in the daily needs of rural communities. In particular (1) they need to resolve the conflicts between resource users and resource managers and (2) there must be an improved, diversified and productive commercial use of the natural resources.

The actions must contribute to improved productivity of degraded land (such as through growth of leguminous trees and agrobiological improvement of degraded soil). They must ensure sustainable resource management.

In some areas, deforestation is continuing at an alarming rate, primarily for maize cultivation, to provide in the daily food needs of the very poor people. Cutting trees for construction poles and firewood is a secondary cause of forest degradation, but considered essential as the rural people have no money to buy such products. This degradation of the forest causes the loss of other sources of income such as woodcrafts and the basket industry. The Eastern Cape Resource Accounting Survey (Hassan & Haveman 1997) indicated a number of wrong perceptions on both sides that relate partly to the real meaning of sustainability and partly to the true dependence of the poor rural communities on the forests for their daily livelihood. This accentuates the need for implementation of joint resource management strategies in the rural areas to resolve the conflicts and to ensure sustainable resource use and socio-economic development.

Development of sustainable resource use from forest involves a process within which the resource managers (often the authorities) and the resource users must (Geldenhuys 2000b):

- Define the products to be used.
- Make an inventory of resource availability and match this with the resource needs.
- Determine the rate of production.
- Make assumptions on aspects not known.
- Set management objectives and guidelines.
- Implement management.

- Monitor.
- Re-evaluate and adapt management.

Resource use should be approached from a business development perspective to focus the attention on critical issues related to market demand, whether it is other rural communities, sophisticated industries (furniture, florist greenery, medicine) or conservation.

Development of small businesses in rural areas, based on sustainable use of forests, is a new approach in South Africa to deal with illegal resource use practices. It was developed with implementation of the harvesting of *Rumohra* fern for the florist industry in a commercial forestry and farming environment (Geldenhuys 1994c). The approach was further advanced with the harvesting of bark for traditional medicine in a rural environment (Geldenhuys 2002, 2004), but also in other areas such as vine harvesting for basket-making (Venter 2000). Businesses in rural areas, based on the use of forest species, could be developed as an approach to improve management of forests for the benefit of rural communities.

Forests play an increasingly important role in providing for the recreation and aesthetics of the growing urban and industrial societies of southern Africa. Many picnic sites, viewpoints, camping sites, forest walks and hiking trails in forests offer unique experiences (Levy 1987, Van Dijk 1987). The care taken with the management of recreation sites has contributed to forest recovery in several areas.

Forests also have cultural importance as burial sites (Netshiungani et al. 1981, McKenzie 1988). Undisturbed forest and wooded copses persist around major grave sites in many parts of South Africa because of the acknowledged importance of the role that ancestral spirits play in daily life and the value of ensuring them peace.

10. Further Research

The recently completed National Forest Type Classification (Von Maltitz et al. 2003) has brought together most of the existing information and knowledge of the natural forests in the different parts of South Africa. Forest inventory data exist for many areas (see Von Maltitz et al. 2003), but the data are not always in a form that would facilitate sustainable resource use, or provide knowledge of the conservation status of important species. What is needed are data on the population demography of the key ecological and economic species, i.e. data on the numbers of a species in all age or size categories. This would indicate what the important species would require for recruitment, establishment and for growth to maturity. There is a considerable amount of data on the recruitment, growth and mortality of forest stands and species (Geldenhuys 1997c, 1998, 2000c), which, after detailed analysis and interpretation, would shed light on the problems of forest dynamics. Prediction of forest dynamics will also require much improved understanding of competitive relationships of forest plants, mutualisms and ecosystem-level functions, including nutrient cycling.

Traditionally, trees and shrubs were the subject of forest research, grossly neglecting the non-woody component. It is becoming increasingly clear (Mucina & Geldenhuys 2002) that this situation is untenable, especially in the light of conservation needs and sustainable use of non-woody forest components. Biodiversity studies in forests are also hampered by our ignorance (or negligence) of epiphytes, herbs and grasses in forest environments. There are many taxonomic and biogeographic surprises out there.

The small and fragmented forests are unlikely to support long-term resource removal, in areas subject to frequent harvesting, that is sustainable (Adie & Goodman 2000). Appropriate utilisation guidelines have to be researched and compiled to enable the long-term utilisation of forest products, such as bark, that is not destructive and would also not change the species composition of the forest or impact on forest integrity.

Management of natural forest has to integrate the knowledge of forest types, the relationship between forest composition and site conditions, the development stage of the vegetation (stand dynamics), the rates of recruitment, growth and mortality, disturbance and recovery processes. For some areas, knowledge and understanding of the forest is advanced (Seydack et al. 1990, Geldenhuys 1996b), but for others it is seriously lacking.

11. Descriptions of Vegetation Units

Zonal & Intrazonal Units

FOz 1 Southern Afrotemperate Forest

Knysna Forests (Acocks 1988). Southern Cape Forests (Phillipson & Russell 1988, Geldenhuys 1993e). Afrotemperate Forests p.p. (Low & Rebelo 1996). Knysna-Tsitsikamma Forests, Swellendam Area Forests, Cape Peninsula Forests and South-western Cape Forests (Bailey et al. 1999). Western Cape Talus Forest, Western Cape Afrotemperate Forest and Southern Cape Afrotemperate Forest (Von Maltitz et al. 2003).

Distribution Western Cape, Eastern Cape and also (only few patches) in Northern Cape Provinces: The largest complex is found in the southern Cape along the narrow coastal strip (250 km long) between Humansdorp in the east and Mossel Bay (Knysna-Tsitsikamma forest region)—here occurring on sheltered seaward slopes, plateaux and coastal scarps. The easternmost outlier forest patches occur near Port Elizabeth, while westwards floristically impoverished forms of these forests occur along the feet of south- and east-facing slopes and in deep kloofs and ravines of the Cape Fold Belt mountains as far as the Cape Peninsula in the west. The northernmost localities are near Vanrhynsdorp Pass and in the Matsikamma Mountains. At altitudes ranging from about 10 m (Tsitsikamma region) to 600 m (most of patches), with notable outliers occurring as high as 1 060 m.

Vegetation & Landscape Features Tall, multilayered afrotemperate forests dominated by yellowwoods (*Afrocarpus falcatus* and *Podocarpus latifolius*), *Ocotea bullata, Olea capensis* subsp. *macrocarpa, Pterocelastrus tricuspidatus, Platylophus trifoliatus* etc. In scree and deep-gorge habitats *Cunonia capensis, Heeria argentea, Metrosideros angustifolia, Podocarpus elongatus* and *Rapanea melanophloeos* predominate. The shrub understorey and herb layers are well developed, especially in mesic and wet habitats.

Geology & Soils Soils varying from shallow (and skeletal) Mispah, Glenrosa and Houwhoek forms to sandy humic Fernwood form, derived from Table Mountain Group sandstones and shales of the Cape Supergroup and partly also from Cape Granite.

Important Taxa Tall Trees: *Afrocarpus falcatus* (d), *Cunonia capensis* (d), *Curtisia dentata* (d), *Nuxia floribunda* (d), *Ocotea bullata* (d), *Olinia ventosa* (d), *Podocarpus elongatus* (d), *P. latifolius* (d), *Pterocelastrus tricuspidatus* (d), *Rapanea melanophloeos* (d), *Ilex mitis*, *Olea capensis* subsp. *macrocarpa*. Small Trees. *Canthium inerme* (d), *Cassine peragua* (d), *Diospyros*

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Figure 12.9 FOz 1 Southern Afrotemperate Forest: Riparian forest with prominent *Cunonia capensis*, *Olinia ventosa* and *Platylophus trifoliatus* in the Disa Kloof, Harold Porter National Botanical Garden near Betty's Bay (Western Cape).

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Figure 12.10 FOz 1 Southern Afrotemperate Forest: Dense warm-temperate forests near Nature's Valley (Western Cape) featuring a dense population of endemic *Strelitzia alba* (Strelitziaceae).

whyteana. Tree Fern: *Cyathea capensis* (d). Herbaceous Climber: *Cissampelos torulosa*. Epithytic Herb: *Angraecum pusillum*. Tall Shrubs: *Burchellia bubalina* (d), *Trichocladus crinitus* (d), *Sparrmannia africana*.Geophytic Herbs: *Blechnum capense* (d), *B. tabulare* (d), *Dietes iridioides* (d), *Rumohra adiantiformis* (d), *Todea barbara* (d), *Oxalis incarnata*. Graminoid: *Oplismenus hirtellus* (d).

Biogeographically Important Taxa ([C]Endemic of Capensis, [W]Western distribution limit) Tall Trees: *Brabejum stellatifolium*[C], *Ochna arborea* var. *arborea*[W]. Small Trees: *Gonioma kamassi*[W] (d), *Heeria argentea*[C] (d), *Metrosideros angustifolia*[C] (d), *Allophylus decipiens*[W], *Brachylaena neriifolia*[C], *Cassine schinoides*[C], *Lachnostylis hirta*[C], *Virgilia divaricata*[C]. Woody Climber: *Asparagus scandens*[C]. Epiphytic Herb: *Mystacidium capense*[W]. Tall Shrub: *Laurophyllus capensis*[C]. Herb: *Gerbera cordata*[W], *Streptocarpus rexii*[W]. Geophytic Herbs: *Liparis capensis*[C]. Graminoids: *Ischyrolepis subverticillata*[C], *Schoenoxiphium lanceum*[C].

Endemic Taxa Tall Tree: *Platylophus trifoliatus* (d). Small Trees: *Apodytes geldenhuysii*, *Cryptocarya angustifolia*, *Virgilia oroboides* subsp. *ferruginea*, *V. oroboides* subsp. *oroboides*. Megaherb: *Strelitzia alba* (d). Geophytic Herbs: *Amauropelta knysnaensis*, *Clivia mirabilis*, *Freesia sparrmannii*, *Polystichum incongruum*.Graminoid: *Schoenoxiphium altum.*

Conservation Least threatened. Target 34%. More than half of the extent of these forests enjoy statutory conservation in the proposed Garden Route National Park (including Tsitsikamma and Wilderness National Parks, several nature reserves and a number of otherwise protected forests formerly under DWAF jurisdiction), Table Mountain National Park, and many nature reserves managed by CapeNature in the Western Cape Province (including Cederberg Wilderness Area, Kogelberg Biosphere Reserve, Boosmansbos Wilderness Area, nature reserves of Jonkershoek, Assegaaibos, Limietberg, Hottentots Holland, Riviersonderend, Marloth, Outeniqua, Swartberg etc.); small portions are also protected in the Oorlogskloof Nature Reserve (Northern Cape) and in the Groendal Wilderness Area and Loerie Nature Reserve (Eastern Cape). Number of privately owned nature reserves in both Western and Eastern Cape also protect some patches of this forest. Unknown portion of the original area (only about 300 ha in the southern Cape; see Geldenhuys 1991) has been transformed for plantations.

Remarks Southern Afrotemperate Forests are species-poorer than those of the mistbelt, but they still support some woody (palaeo)endemic elements such as *Cunonia capensis*, *Cryptocarya angustifolia, Heeria argentea*, *Metrosideros angustifolia*, *Platylophus trifoliatus*, *Podocarpus latifolius* and *Afrocarpus falcatus.*

References Phillips (1931), Laughton (1937), Taylor (1955, 1996), Von Breitenbach (1974), Campbell & Moll (1977), McKenzie et al. (1977), McKenzie (1978), Geldenhuys (1982, 1987, 1992a, 1993c, e, 1994b, 1997a), Hanekom et al. (1989), Masson & McKenzie (1989), Masson (1990), McKenzie et al. (1990), Vermeulen (1995), Von Maltitz et al. (2003), Geldenhuys & Mucina (2006).

FOz 2 Northern Afrotemperate Forest

Mountain *Podocarpus* Forest (Edwards 1967). Kloof Forest (Coetzee 1974). Afromontane *Podocarpus* Forest (Cooper 1985). Highland Sourveld p.p. (Acocks 1988). Montane *Podocarpus* Forests (Everard 1992). Marekele Afromontane Forest, Northern Highveld Forest, Drakensberg Montane Forest and Low Escarpment Mistbelt Forest (Von Maltitz et al. 2003).

Distribution Free State, KwaZulu-Natal, Mpumalanga, North-West, Gauteng and Limpopo Provinces (as well as Lesotho): Restricted to mountain kloofs and low ridges (Strydpoortberg, Waterberg, Pilanesberg, Witwatersrand, Magaliesberg, Suikerbosrand, Sekhukhuneland) interrupting the relatively flat northern highveld. This group also comprises forests found in kloofs along the northern and eastern flanks of the Drakensberg and those found on the slopes and scarps of the Low Escarpment between Van Reenen's Pass and Pongola Bush near Piet Retief. The westernmost localities of these forests are found in the Koranaberg (close to Thaba 'Nchu). The remnants of forests rich in afrotemperate elements in Lesotho might also be classified within this vegetation unit. Most patches occur at altitudes between 1 450 and 1 900 m, with outliers as low as 1 100 m and around 2 000 m.

Vegetation & Landscape Features Low (in the Low Escarpment region with canopy reaching up to 20 m), relatively species-poor forests of afromontane origin and some of them still showing clear afromontane character. Found as small patches in kloofs and on sub-ridge scarps at high altitudes (1 500–1 900 m). Canopy dominated usually by *Podocarpus latifolius*, *Olinia emarginata*, *Halleria lucida*, *Scolopia mundii* and rarely also by *Widdringtonia nodiflora*, in drier facies also by *Pittosporum viridiflorum*, *Celtis africana, Mimusops zeyheri, Nuxia congesta* and *Combretum erythrophyllum*. *Xymalos monospora* sometimes dominate patches of species-poor mistbelt forests of northern KwaZulu-Natal.

Geology & Soils Shallow acidic soils over sandstones of the Karoo Supergroup, quartzites and rarely also volcanic rocks of Ventersdorp Supergroup and intrusive diabases of Pretoria Igneous Complex.

Important Taxa Tall Trees: *Celtis africana* (d), *Halleria lucida* (d), *Olinia emarginata* (d), *Pittosporum viridiflorum* (d), *Podocarpus latifolius* (d), *Rothmannia capensis* (d), *Scolopia mundii* (d), *Afrocarpus falcatus*, *Buddleja saligna*, *Dais cotinifolia*, *Ilex mitis*. Small Trees: *Acalypha glabrata* (d), *Buddleja salviifolia* (d), *Calpurnia aurea* (d), *Combretum erythrophyllum* (d), *Diospyros lycioides* subsp. *guerkei* (d), *D. whyteana* (d), *Euclea crispa* subsp. *crispa* (d), *Widdringtonia nodiflora* (d), *Bowkeria verticillata*, *Canthium ciliatum*, *Leucosidea sericea*, *Scolopia flanaganii*. Woody Climber: *Cassinopsis ilicifolia* (d). Tall Shrubs: *Myrsine africana* (d), *Cliffortia nitidula*. Soft Shrubs: *Isoglossa grantii* (d), *Hypoestes aristata*, *Plectranthus fruticosus*. Herbs: *Plectranthus grallatus* (d), *P. hereroensis* (d), *Peperomia retusa*, *Streptocarpus haygarthii*, *S. pusillus*. Geophytic Herbs: *Blechnum attenuatum* (d), *Asplenium aethiopicum*, *Polystichum luctuosum*. Graminoids: *Carex spicato-paniculata* (d), *Oplismenus hirtellus* (d), *Cyperus albostriatus*, *Schoenoxiphium lehmannii*, *Thamnocalamus tessellatus*.

Endemic Taxa Tall Tree: *Scolopia oreophila*. Small Tree: *Maytenus albata*. Tall Shrub: *Sparrmannia ricinocarpa*. Herb: *Streptocarpus polyanthus* subsp. *dracomontanus*.

Conservation Least threatened. Target 31%. About 30% statutorily conserved in uKhahlamba Drakensberg Park, Phongola Bush, Vryheid Mountain, Poccolan/Robinson's Bush, Ngome and Ncandu Nature Reserves, Magaliesberg Nature Area, Merville Ridge, Paardeplaats, Rustenburg, Suikerbosrand Nature Reserves, Marekele National Park and Pilanesberg Game Reserve. Some private nature reserves (e.g. Mooibron, Mhlongamvula, Tafelkop, Oudehoutdraai, Oshoek and Ossewakop) protect some patches too. Occasional hot fires encroaching from the surrounding savanna woodlands, uncontrolled timber extraction, medicinal-plant harvesting, and grazing in forest can be viewed as the current major threats (Von Maltitz et al. 2003).

Remarks In the northern highveld, these forest patches are either imbedded within Savanna Biome or straddle an ecotone between sourveld grassland and subtropical savanna of the Central Bushveld. This group of forests is a 'high-altitude' analogue to 'high-latitude' afrotemperate forests of the southern and western Cape. The major unifying trait of the two groups of forests mentioned above is impoverished floristic composition when compared to Northern Mistbelt Forest and Southern Mistbelt Forest (both also of afrotemperate character).

References Roberts (1961), Van Vuuren (1961), Killick (1963), Van Vuuren & Van der Schijff (1970), Van Zinderen Bakker (1971, 1973), Coetzee (1974, 1975), Van der Meulen (1978, 1979), Bredenkamp & Theron (1978, 1980), Westfall (1981), Cooper (1985), Westfall et al. (1985), Everard (1986), Behr & Bredenkamp (1988), Du Preez & Bredenkamp (1991), Du Preez et al. (1991), Smit et al. (1993), Hill (1996), Eckhardt et al. (1997), Ellery et al. (2001), Siebert (2001), Van Staden (2002), Siebert et al. (2003), Von Maltitz et al. (2003), Van Staden & Bredenkamp (2005, 2006), Geldenhuys & Mucina (2006).

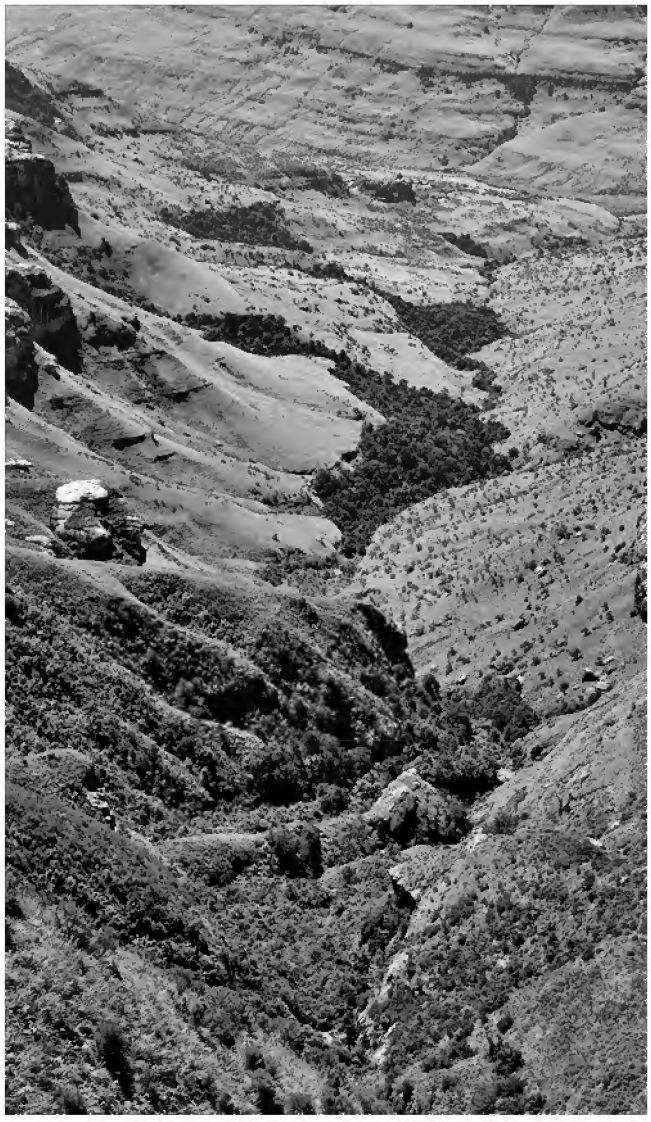

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Figure 12.11 FOz 2 Northern Afrotemperate Forest: Kloof forests with *Podocarpus latifolius* above Thendele Camp in uKhahlamba-Drakensberg Park near Bergville, KwaZulu-Natal.

FOz 3 Southern Mistbelt Forest

Mist Belt Mixed *Podocarpus* Forests (Edwards 1967). Transkei and Natal Montane Forests p.p. & Eastern Cape Montane Forests (Phillipson & Russell 1988). High Altitude Afrotemperate Forests, Middle Altitude Afrotemperate Forests, Mistbelt Afrotemperate Forests, Moist Afrotemperate Forests (Cawe 1996, Cawe & McKenzie 1989). Afromontane Forests p.p. (Low & Rebelo 1996). Amathole Forest Complex (Bailey et al. 1999). Eastern Mistbelt Forest, Transkei Mistbelt Forest and Amatole Mistbelt Forest (Von Maltitz et al. 2003).

Distribution KwaZulu-Natal and Eastern Cape Provinces: Forest patches varying in size, occurring in fire-shadow habitats on south- and southeast-facing slopes and located along the Great Escarpment, spanning a large area from Somerset East, the Amathole Mountains, scarps of Transkei to the KwaZulu-Natal Midlands as far east as Ulundi. In KwaZulu-Natal these forests are found in a wide band sandwiched between the Drakensberg Montane Forests and Northern KwaZulu-Natal Mistbelt Forests at higher altitudes and Eastern Scarp Forests at lower altitudes. Belts of forest patches belonging to this vegetation unit occur in the Baviaanskloof Mountains, Zuurberg Mountains and in the region spanning Grahamstown and King William's Town. Found at altitudes spanning 850–1 600 m (most patches between 1 000 and 1 400 m).

Vegetation & Landscape Features On the Great Escarpment (Amathole, Transkei Escarpment) and in the KwaZulu-Natal Midlands these forests are tall (15–20 m tall) and multilayered (having two layers of trees, a dense shrubby understorey and a well-developed herb layer). The forests found on low-altitude scarps are low (in places having the character of a scrub forest), and although less structured into different tree layers, they are still species-rich. The tall forests show a mix of coarse-grained, canopy gap/disturbance-driven dynamics and fine-grained, regeneration characteristics. The Amathole mistbelt forests are dominated by emergent trees of *Afrocarpus falcatus* and a range of deciduous and semi-deciduous species such as *Celtis africana*, *Calodendrum capense*, *Vepris lanceolata* and *Zanthoxylum davyi*. Further east (Transkei, KwaZulu-Natal Midlands) *Podocarpus henkelii* becomes prominent in the canopy layer. Deciduous elements play an important role.

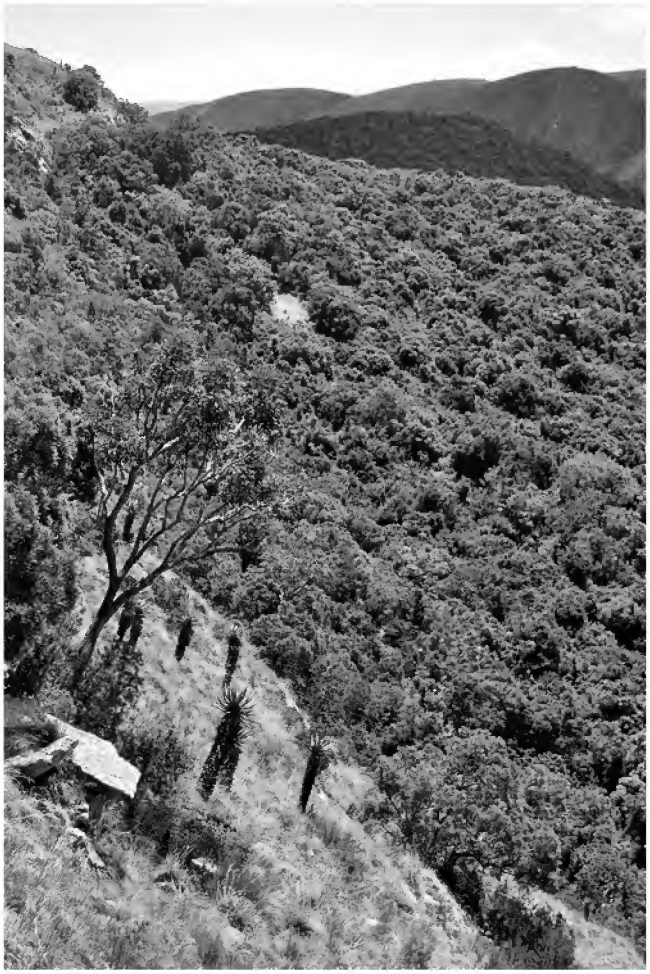

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Figure 12.12 FOz 3 Southern Mistbelt Forest: Patch of Amathole Mistbelt Forest in the Zuurberg (Eastern Cape).

Geology & Soils Some of the soils are deep, loamy and with high nutrient status, developed on weathered dolerite intrusions or mudstones, shales and sandstones of the Karoo Supergroup (on Great Escarpment). The soils supporting forests of low-lying scarps are shallower as they developed on quartzitic Witteberg Sandstones or sandstones of the Karoo Supergroup.

Important Taxa Tall Trees: *Afrocarpus falcatus* (d), *Apodytes dimidiata* subsp. *dimidiata* (d), *Celtis africana* (d), *Chionanthus foveolatus* subsp. *foveolatus* (d), *C. peglerae* (d), *Cunonia capensis* (d), *Curtisia dentata* (d), *Kiggelaria africana* (d), *Olea capensis* subsp. *macrocarpa* (d), *Podocarpus henkelii* (d), *P. latifolius* (d), *Protorhus longifolia* (d), *Ptaeroxylon obliquum* (d), *Rapanea melanophloeos* (d), *Rhus chirindensis* (d), *Scolopia mundii* (d), *S. zeyheri* (d), *Vepris lanceolata* (d), *Xymalos monospora* (d), *Combretum kraussii*, *Elaeodendron croceum*, *E. zeyheri*, *Halleria lucida*, *Mimusops obovata*, *Ochna arborea* var. *arborea*, *Ocotea bullata*, *Pleurostylia capensis*, *Psydrax obovata* subsp. *elliptica*, *Zanthoxylum davyi*. Small Trees: *Canthium ciliatum* (d), *C. inerme* (d), *Cassipourea flanaganii* (d), *Clausena anisata* (d), *Eugenia capensis* (d), *Gymnosporia buxifolia* (d), *Maerua racemulosa* (d), *Ochna serrulata* (d), *Scutia myrtina* (d), *Trichocladus ellipticus* (d), *Trimeria grandifolia* (d), *Allophylus dregeanus*, *Diospyros whyteana*, *Mystroxylon aethiopicum*, *Rinorea angustifolia*. Tall Shrubs: *Burchellia bubalina* (d), *Carissa bispinosa* subsp. *zambesiensis* (d), *Grewia occidentalis* (d), *Calodendrum capense*, *Diospyros scabrida* var. *cordata*, *Hyperacanthus amoenus*, *Maesa alnifolia*. Low Shrub: *Azima tetracantha* (d). Soft Shrubs: *Hypoestes aristata* (d), *Isoglossa woodii* (d). Herbs: *Streptocarpus daviesii*, *S. haygarthii*, *S. pentherianus*, *S. polyanthus* subsp. *comptonii*, *S. polyanthus* subsp. *polyanthus*. Geophytic Herbs: *Dietes iridioides* (d), *Dryopteris inaequalis* (d), *Polystichum pungens* (d). Graminoid: *Oplismenus hirtellus* (d).

Endemic Taxa Tall Shrub: *Eugenia zuluensis* (d). Herbs: *Plectranthus elegantulus*, *P. rehmannii*, *Pyrrosia africana*, *Streptocarpus bolusii*, *S. candidus*, *S. fanniniae*, *S. silvaticus*.

Conservation Least threatened. Target 30%. Some 8% statutorily conserved (including forests under DWAF jurisdiction) in the Eastern Cape encompassing the Bosberg Nature Reserve, Greater Addo Elephant National Park as well as Hogsback, Kologha, Isidenge, Kubusi, Katberg and Nabakyu State Forests. In KwaZulu-Natal these forests are statutorily protected in Impendle, Igxalingenwa, Karkloof and Qudeni Nature Reserves. Several private reserves protect smaller patches. About 5% has been transformed for plantations. Invasive aliens include *Solanum mauritianum*, *Rubus* species and several *Acacia* and *Eucalyptus* species. Uncontrolled harvesting of timber, poles and firewood, overexploitation of non-timber forest products and mismanagement of fire and burning regimes in surrounding grasslands are considered as current major threats (Von Maltitz et al. 2003).

Remarks All mistbelt forests are species-rich afrotemperate forests containing an important share of subtropical floral elements.

Podocarpus henkelii is a near-endemic species for this vegetation unit, as it marginally occurs in the Northern Afrotemperate Forests as well.

References Story (1952), Edwards (1967), Moll (1976), Cooper (1985), Cawe (1986, 1996), Phillipson (1987), Cawe & McKenzie (1989), Everard (1992), Geldenhuys (1992a), Everard & Hardy (1993), Everard et al. (1995), Geldenhuys & Rathogwa (1997), Von Maltitz et al. (2003), Geldenhuys & Mucina (2006).

FOz 4 Northern Mistbelt Forest

Soutpansberg Forests & Transvaal Drakensberg Escarpment Forests (Cooper 1985). Transvaal Forests (Phillipson & Russell 1988). Afromontane Forest p.p. (Low & Rebelo 1996). Northern Mistbelt Forest and Mpumalanga Mistbelt Forest (Von Maltitz et al. 2003). Limpopo Mistbelt Forests (Geldenhuys & Mucina 2005).

Distribution Limpopo and Mpumalanga Provinces as well as in Swaziland: Occurring along the Soutpansberg from Blouberg in the northwest to the Samandou Plateau in the northeast and further southwards (along the Northern Escarpment) from Abel Erasmus Pass (Olifants River) to the surroundings of Badplaas and Barberton. In northern Swaziland in fire refugia and cooler sheltered areas along a north-south trending lowveld/highveld transition. Most of the patches occur in an altitudinal belt spanning 1 050 to1 650 m.

Vegetation & Landscape Features Tall, evergreen afrotemperate mistbelt forests occurring primarily in east-facing fire refugia such as subridge scarps and moist sheltered kloofs where they form small, fragmented patches. The most common canopy trees include *Xymalos monospora*, *Podocarpus latifolius*, *Combretum kraussii*, *Cryptocarya transvaalensis* *Schefflera umbellifera*, *Syzygium gerrardii*, *Olea capensis* subsp. *macrocarpa*, *Psydrax obovata* subsp. *elliptica*, *Pterocelastrus galpinii*. In the understorey *Psychotria zombamontana*, *Canthium kuntzeanum*, *Gymnosporia harveyana, Peddiea africana*, *Pavetta inandensis*, *Mackaya bella*, *Sclerochiton harveyanus* etc. are found. The herb layer supports a number of dominating Acanthaceae (*Isoglossa*), Lamiaceae (*Plectranthus*, *Stachys*) and Rubiaceae (*Galopina*) herbs and so called 'soft shrubs', geophytic herbs and ferns (*Asplenium, Dryopteris, Polystichum*). Of lianas and climbers *Dalbergia armata*, *Combretum edwardsii*, *Jasminum abyssinicum, Rhoicissus rhomboidea* and *Keetia gueinzii* are the most conspicuous vines, as is the scandent grass *Prosphytochloa prehensilis*.

Geology & Soils Highly weathered, clayey soils mainly of Avalon and Hutton soil forms, derived from shales (Pretoria Group), quartzite (Black Reef Formation), dolomite (Chuniespoort Group), granite (Nelspruit Basement) and diabase (Mokolian intrusives).

Important Taxa Tall Trees: *Brachylaena transvaalensis* (d), *Combretum kraussii* (d), *Curtisia dentata* (d), *Drypetes gerrardii* (d), *Kiggelaria africana* (d), *Ocotea kenyensis* (d), *Olea capensis* subsp. *macrocarpa* (d), *Podocarpus latifolius* (d), *Psydrax obovata* subsp. *elliptica* (d), *Rhus chirindensis* (d), *Schefflera umbellifera* (d), *Syzygium gerrardii* (d), *Xymalos monospora* (d), *Aphloia theiformis*, *Chionanthus battiscombei*, *C. foveolatus* subsp. *major*, *Maytenus acuminata*, *Pterocelastrus galpinii*, *Rapanea melanophloeos*, *Rothmannia capensis*, *Trichilia dregeana*. Small Trees: *Cassipourea malosana* (d), *Oxyanthus speciosus* subsp. *gerrardii* (d), *Englerophytum magalismontanum*, *Gymnosporia harveyana*, *Mackaya bella*, *Ochna arborea* var. *oconnorii*, *Peddiea africana*, *Rinorea angustifolia*. Woody Climbers: *Acacia ataxacantha* (d), *Keetia gueinzii* (d), *Rhoicissus rhomboidea* (d), *Bauhinia galpinii*, *Dalbergia armata*. Climbing Graminoid: *Prosphytochloa prehensilis* (d). Tall Shrubs: *Psychotria capensis* (d), *Canthium kuntzeanum*, *Carissa bispinosa* subsp. *zambesiensis*, *Pavetta kotzei*, *Sclerochiton harveyanus*. Soft Shrubs: *Galopina circaeoides*, *Hypoestes triflora*. Herbs: *Begonia sonderiana*, *Plectranthus rubropunctatus*, *P. tetragonus*, *Streptocarpus meyeri*, *S. pentherianus*. Geophytic Herbs: *Dietes iridioides* (d), *Asplenium aethiopicum*, *A. boltonii*, *A. splendens*, *Crocosmia aurea*, *Dryopteris inaequalis*, *Elaphoglossum acrostichoides*, *Polypodium polypodioides* subsp. *ecklonii*, *Polystichum macleae*, *Pteris catoptera*. Graminoids: *Carex spicato-paniculata* (d), *Cyperus albostriatus* (d), *Oplismenus hirtellus* (d).

Biogeographically Important Taxa ([S]Southern distribution limit, [B]Endemic of Barberton Centre) Tall Tree: *Anthocleista grandiflora*[S], *Faurea galpinii*. Tall Shrubs: *Psychotria zombamontana*[S] (d), *Coptosperma rhodesiacum*[S]. Soft Shrub: *Duvernoia adhatodoides*[B]. Megaherbs: *Ensete ventricosum*[S], *Strelitzia caudata*[S]. Herbs: *Plectranthus swynnertonii*[S], *Sphaerocionium capillare*[S].

Endemic Taxa Tall Trees: *Cryptocarya transvaalensis* (d), *Ochna gamostigmata*. Small Trees: *Dombeya pulchra*, *Heteropyxis canescens*. Epiphytic Herb: *Mystacidium brayboniae*. Tall Shrub: *Pavetta barbertonensis* (d). Herbs: *Streptocarpus davyi*, *S. fenestra-dei*, *S. micranthus*, *S. parviflorus*, *S. roseo-albus*, *S. wilmsii*. Geophytic Herb: *Clivia caulescens* (d).

Conservation Least threatened. Target 30%. About 10% statutorily conserved in Blyde River Canyon, Lekgalameetse, Songimvelo, Makobulaan, Malalotja, Nelshoogte, Barberton, Starvation Creek Nature Reserves. More than 25% enjoys pro-

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Figure 12.13 FOz 4 Northern Mistbelt Forest: Stand of tree fern *Cyathea capensis* on the edge of mistbelt forest in a shady gully below the escarpment near Graskop (Mpumalanga).

tection in privately owned nature reserves, including for instance Wolkberg Wilderness Area, In-De-Diepte, Sudwala, Mac Mac, Buffelskloof, Mount Sheba etc. Aliens such as *Solanum mauritianum, Caesalpinia decapetala, Acacia mearnsii* and *Lantana camara* can be locally of concern. Encroaching subsistence agriculture, firewood collection in communal areas, and selective harvesting of bark are viewed as serious threats (Von Maltitz et al. 2003). Below the escarpment between Mariepskop and Graskop, the natural forest has expanded into former grassland areas due to the protection of the timber plantations against fire (when comparing the current forest areas with aerial photographs of the 1930s, before the establishment of the plantations) (Grossman 2005).

Remarks These forests border on sourveld grasslands on their upper boundary, whereas they often border on bushveld on their lower boundary. The Northern Mistbelt Forests are typically species rich, containing a mixture of afrotemperate elements and species of subtropical provenience, indicating a floristic (and possibly also biogeographic-evolutionary) link of these forests to the Scarp Forests. This phenomenon is clearly observed along the Northern Escarpment below God's Window and Marieskop, and in the Barberton region (Morgenthal & Cilliers 1999).

References Van der Schijff & Schoonraad (1971), Scheepers (1978), Deall et al. (1989), Von Breitenbach (1990), Matthews et al. (1992), Geldenhuys & Murray (1993), Geldenhuys & Pieterse (1993), Masson (1994), Morgenthal & Cilliers (1999), Stalmans et al. (1999), Geldenhuys & Venter (2002), Von Maltitz et al. (2003), Lötter & Beck (2004), Geldenhuys & Mucina (2006).

FOz 5 Scarp Forest

Semi-Coast Forest (Edwards 1967). Tongaland-Pondoland Undifferentiated Forest p.p. (White 1983). Coast Scarp Forest (Cooper 1985). Pondoland Coastal Plateau Sourveld p.p. & Transitional Coastal Forest (Acocks 1988). Natal and Transkei Coastal Forests p.p. (Phillipson & Russell 1988). Ngoye Group Forests p.p. (MacDevette et al. 1989). Pondoland Coast Forest & South Coast Forest (Cooper & Swart 1992). Moist Subtropical Forest (Cawe 1996). Coastal Forest p.p. (Low & Rebelo 1996). Eastern Scarp Forest, Pondoland Scarp Forest and Transkei Coastal Scarp Forest (Von Maltitz et al. 2003).

Distribution Eastern Cape, KwaZulu-Natal and Mpumalanga Provinces as well as in Swaziland (and possibly also in Mozambique): An archipelago of scattered patches (some of them large, such as Ongoye) spanning southern Mpumalanga (Crocodile River Gorge), the southern part of Lebombo Mountains (KwaZulu-Natal) and reaching nearly as far as Kei River Mouth on the Transkei coast. Patches of this forest lie as far as 140 km inland (Mpumalanga), but extend increasingly closer to the sea in a southward direction—in Pondoland, and southern Transkei they occur at the coast or in deep gorges, often associated with krantzes, scarps and coastal platforms. Most of the patches occur at low altitudes between 50 and 600 m.

Vegetation & Landscape Features Tall (15–25 m), species-rich and structurally diverse, multilayered forests, with well-developed canopy and understorey tree layers, but a poorly developed herb layer. Buttressed stems are common in the Scarp Forest. The most conspicuous trees are *Buxus macowanii*, *B. natalensis*, *Drypetes gerrardii*, *Englerophytum natalense*, *Harpephyllum caffrum*, *Heywoodia lucens*, *Memecylon natalense*, *Millettia grandis*, *Oricia bachmannii*, *Philenoptera sutherlandii*, *Rinorea angustifolia*, *Rothmannia globosa* and *Umtiza listeriana*.

Geology & Soils Natal Sandstone outcrops (Msikaba Group Sandstones in Pondoland) as well as syenitic granite, rhyolite of the Jozini Formation of the Lebombo Group (Karoo Supergroup) and other Karoo sedimentary rocks; supporting nutrient poor, leached and shallow soils.

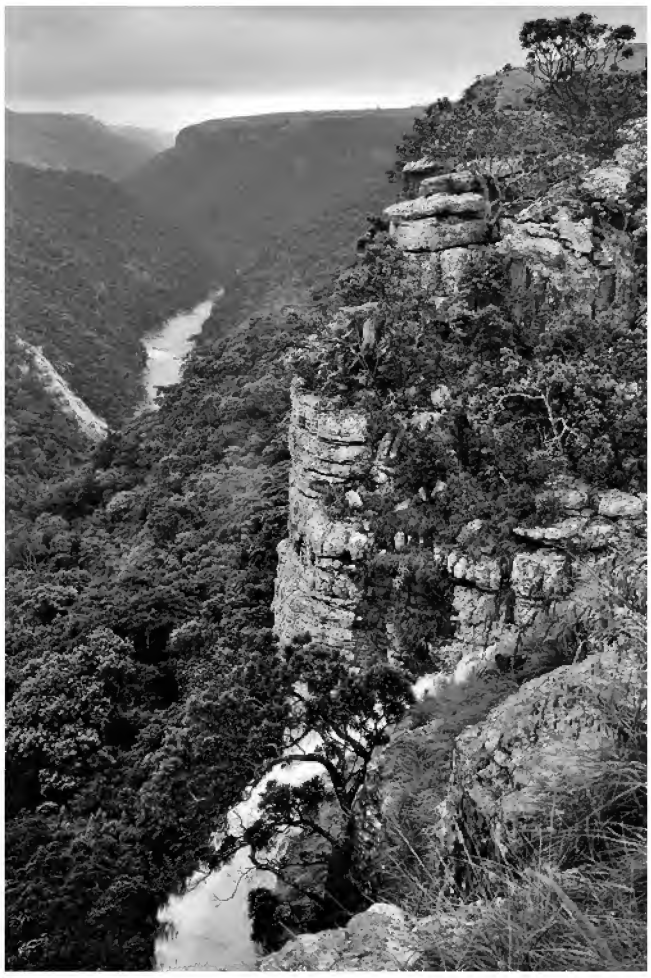

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Figure 12.14 FOz 5 Scarp Forest: Endemic-rich subtropical scarp forests on Msikaba sandstones in the gorge of the Umtamvuna River near Port Edward (southern KwaZulu-Natal).

Important Taxa Tall Trees: *Buxus natalensis* (d), *Drypetes gerrardii* (d), *Englerophytum natalense* (d), *Harpephyllum caffrum* (d), *Heywoodia lucens* (d), *Rothmannia globosa* (d), *Commiphora harveyi*, *C. woodii*, *Drypetes arguta*, *Manilkara discolor*, *Nectaropetalum capense*, *Nuxia congesta*, *Olinia emarginata*, *Ptaeroxylon obliquum*, *Pterocelastrus tricuspidatus*, *Vitellariopsis marginata*. Small Trees: *Buxus macowanii* (d), *Rinorea angustifolia* (d), *Dombeya cymosa*, *Encephalartos natalensis*, *E. villosus*, *Ochna natalitia*, *Strychnos henningsii*, *S. mitis*. Herbaceous Climbers: *Flagellaria guineensis, Thunbergia alata*. Tall Shrubs: *Memecylon natalense* (d), *Eugenia natalitia*. Low Shrub: *Stangeria eriopus*. Soft Shrub: *Piper capense*. Herbs: *Begonia dregei*, *B. homonyma*, *Streptocarpus grandis*, *S. johannis*. Geophytic Herb: *Clivia miniata*.

Biogeographically Important Taxon Tall Shrub: *Pseudoscolopia polyantha* (disjunct populations also in Capensis in AZa 1 Fynbos Riparian Vegetation).

Endemic Taxa Tall Trees: *Millettia grandis* (d), *Oricia bachmannii* (d), *Philenoptera sutherlandii* (d), *Umtiza listeriana* (d), *Celtis mildbraedii*, *Colubrina nicholsonii*, *Cryptocarya myrtifolia*, *C. wyliei*, *Dahlgrenodendron natalense*, *Jubaeopsis caffra*, *Manilkara nicholsonii*, *Maytenus oleosa*, *Pseudosalacia streyi*, *Rinorea domatiosa*. Small Trees: *Alberta magna*, *Albizia suluensis*, *Apodytes abbottii*, *Canthium vanwykii*, *Encephalartos woodii* (extinct in the wild), *Gerrardanthus tomentosus*, *Rhynchocalyx lawsonioides*, *Tarchonanthus trilobus* var. *trilobus*. Woody Climber: *Podranea ricasoliana* (d). Epiphytic Herb: *Bolusiella*

maudiae. Epiphytic Shrub: *Dermatobotrys saundersii*. Epiphytic Parasitic Shrubs: *Actinanthella wyliei*, *Helixanthera woodii*. Tall Shrubs: *Eugenia simii*, *E. verdoorniae*, *Gymnosporia bachmannii*, *Justicia bolusii*, *J. petiolaris* subsp. *bowiei*, *Oxyanthus pyriformis*, *Putterlickia retrospinosa*. Soft Shrubs: *Heterosamara galpinii*, *Metarungia galpinii*. Herbs: *Impatiens flanaganiae*, *Plectranthus oribiensis*, *P. praetermissus*, *Streptocarpus fasciatus*, *S. kentaniensis*, *S. lupatanus*, *S. porphyrostachys*, *S. primulifolius* subsp. *formosus*. Geophytic Herbs: *Clivia robusta* (d), *C. gardenii*. Succulent Herbs: *Plectranthus ernstii*, *P. hilliardiae* subsp. *australis*, *P. hilliardiae* subsp. *hilliardiae*, *P. oertendahlii*, *P. saccatus* var. *longitubus*.

Conservation Least threatened in protected areas, but exposed to over-exploitation elsewhere. Target 40%. More than 20% statutorily conserved in Umtiza and Manubi Nature Reserves, Dwesa-Cwebe Wildlife Reserve & Marine Sanctuary, Hluleka, Mount Thesiger, Umkambati, Umtamvuna, Oribi Gorge, Vernon Crookes, Krantzkloof, Nkandla, Ongoye, Dlinza, Entumeni, Ghost Mountain and Hlatikulu (Gwalinweni) Nature Reserves as well as in Hluhluwe-iMfolozi Park. Still most of the approximately 70 smaller scarp forests between Durban and Umtamvuna are not protected. Proclamation of the planned Pondoland National Park is expected to improve the conservation status of these unique forests along the Wild Coast. Smaller patches of the northern scarp forests are protected in the Barberton area, in southern Kruger National Park and in some Swaziland nature reserves. Almost 5% has been transformed for cultivation or plantations. Aliens such as *Chromolaena odorata, Solanum mauritianum, Melia azedarach, Lantana camara* and *Litsea sebifera* are of concern locally. Collapse of traditional authorities in both Eastern Cape (especially in Transkei and in KwaZulu) has led to uncontrolled use of forests formerly protected under the authority of headmen and chiefs. Bark stripping, muthi collection, deadwood extraction, and land-claims may become other major sources of threat to the existence of some forest patches (Von Maltitz et al. 2003). *Dahlgrenodendron natalense* and *Metarungia galpinii* are listed as endangered. *Encephalartos ngoyanus*, *Eugenia simii*, *Jubaeopsis caffra* and *Rhynchocalyx lawsonioides* are vulnerable. *Encephalartos woodii* (formerly found only in the Ongoye Forest) is extinct in the wild, and survives in about five individuals in various living botanical collections.

Remarks Biogeographically (and from the point of view of biodiversity) this is probably the most valuable forest in South Africa housing many endemic species, six endemic genera and one endemic family (Rhynchocalycaceae) of trees and relict occurrences of small populations of *Encephalartos,* suggesting that this vegetation unit is biogeographically ancient. The endemism in the herbaceous understorey is also high, particularly in the genera *Plectranthus* and *Streptocarpus*. The Pondoland Scarp Forest is a core vegetation unit of the Pondoland Centre of Endemism as defined by Van Wyk & Smith (2001).

References Huntley (1965), Van Wyk (1981, 1989), Nicholson (1982), Whateley & Porter (1983), Cooper (1985), Acocks (1988), MacDevette et al. (1989), Cawe (1990, 1996), Cooper & Swart (1992), Van Wyk & Everard (1993a, b), Everard et al. (1995), Glen (1996), Jacobs (1996), Van Wyk & Smith (2001), Von Maltitz et al. (2003), Geldenhuys & Mucina (2006).

FOz 6 Southern Coastal Forest

Coastal Forest (Taylor 1961, Knight 1989). Coastal Dune Bush (Comins 1962). Alexandria Forest (Phillipson & Russell 1978). Alexandria Forest p.p. (Acocks 1988). Mature Dune Forests (Burns 1986, Burns & Raal 1993). Coastal Forest p.p. (Low & Rebelo 1996). Eastern Cape Dune Forest, Albany Coastal Forest and Western Cape Milkwood Forest (Von Maltitz et al. 2003).

Distribution Eastern Cape and Western Cape Provinces: Coastal plains between Alexandria and Van Stadens River canyon (west of Port Elizabeth) and on coastal dunes of the Eastern Cape. Also found at low altitudes (close to the sea) in deeply incised river valleys in the Albany District surrounded by subtropical succulent thickets. The westernmost forest type of this group is the Western Cape Milkwood Forest found as an interrupted belt of patches stretching along the southern seaboard between Nature's Valley (Plettenberg Bay) and Llandudno (Cape Town). At low altitudes between 20 and 340 m (most patches).

Vegetation & Landscape Features Generally low forests dominated by *Celtis africana*, *Sideroxylon inerme*, *Mimusops caffra* and *Dovyalis rotundifolia*. In the eastern regions of the distribution area, having well-developed low-tree and shrub (*Brachylaena discolor*, *Strychnos decussata*, *Euclea natalensis*, *Dracaena aletriformis* etc.) as well as herb (*Isoglossa woodii*, *Hypoestes aristata*, *Laportea grossa*, *Oxalis pes-caprae*) layers, becoming increasingly floristically and structurally impoverished in a westward direction.

Geology & Soils Well-drained sandy soils of coastal (dune) origin over sedimentary rocks of Alexandria and Nanaga Formations of the Algoa Group. Loamy skeletal soils are supported by the Bokkeveld Group sediments, while deep, nutrient-rich sandy soils over aeolinite or limestone of Bredasdorp Group. The patches situated deeper inland (such as those in Albany region) are found at colluvial valley-bottom sediments derived from Karoo Supergroup shales.

Important Taxa Tall Trees: *Celtis africana* (d), *Ficus burkei* (d), *Mimusops caffra* (d), *Nuxia congesta* (d), *Rhus chirindensis* (d), *Schotia latifolia* (d), *Sideroxylon inerme* (d), *Vepris lanceolata* (d), *Afrocarpus falcatus*. Small Trees: *Allophylus natalensis* (d), *Brachylaena discolor* subsp. *discolor* (d), *Diospyros natalensis* (d), *Euclea natalensis* (d), *E. racemosa* (d), *Gymnosporia buxifolia* (d),

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Figure 12.15 FOz 6 Southern Coastal Forest: Remnants of milkwood (*Sideroxylon inerme*) dune forests in Gordon's Bay (Western Cape).

Maytenus undata (d), *Mystroxylon aethiopicum* (d), *Strychnos decussata* (d), *Trichocladus ellipticus* (d), *Atalaya capensis*, *Brachylaena ilicifolia*, *Encephalartos altensteinii*. Succulent Tree: *Euphorbia grandidens*. Woody Climbers: *Behnia reticulata* (d), *Rhoicissus tomentosa* (d), *Tecoma capensis*. Succulent Woody Climber: *Aloe ciliaris*. Herbaceous Climbers: *Cissampelos torulosa*, *Cynanchum obtusifolium*. Tall Shrubs: *Carissa bispinosa* subsp. *bispinosa* (d), *Hyperacanthus amoenus* (d), *Maytenus lucida*, *Olea exasperata, Rhus glauca*. Low Shrub: *Phyllanthus heterophyllus*. Soft Shrubs: *Euphorbia kraussiana* (d), *Hypoestes aristata* (d), *Isoglossa woodii* (d). Megaherbs: *Dracaena aletriformis* (d). Herb: *Laportea grossa* (d). Geophytic Herb: *Oxalis pes-caprae* (d). Succulent Herbs: *Sansevieria hyacinthoides* (d). Graminoids: *Cyperus albostriatus* (d), *Ehrharta erecta* (d), *Oplismenus hirtellus* (d).

Biogeographically Important Taxa (Southern distribution limit) Tall Tree: *Erythrina caffra* (d). Small Trees: *Dovyalis rotundifolia* (d), *Deinbollia oblongifolia*.

Endemic Taxon Small Tree: *Sterculia alexandri*.

Conservation Least threatened. Target: 40%. More than half of the area of these forests is under statutory conservation since the frontal dune cordons along the Eastern Cape coast fall largely on state-owned land. The Eastern Cape Dune Forests (*sensu* Von Maltitz et al. 2003) are relatively well-preserved by Eastern Cape government authorities in Cape Morgan, Bosbokstrand, Cape Henderson, Kwelera, Three Sisters, Joan Muirhead and Woody Cape Nature Reserves; the latter is now part of the Greater Addo Elephant National Park. The Albany Coastal Forests are protected in the Greater Addo Elephant National Park (including the extensive Alexandria Forest), Waters Meeting, Kap River, Thomas Baines, Peddlar's Bush, The Island and Maitland River Nature Reserves. The Western Cape Milkwood Forests (*sensu* Von Maltitz et al. 2003) are well preserved in Goukamma Nature Reserve and Wilderness National Park (now incorporated into the Garden Route National Park), De Hoop, De Mond and Walker Bay Nature Reserves. A number of private reserves protect patches of the Southern Coastal Forests both in the Eastern Cape and Western Cape. About 6% has been transformed mainly for cultivation or by urbanisation. Invasion by woody aliens such as *Acacia cyclops, A. saligna* and *Casuarina equisetifolia* are a serious concern especially on the dunes. The most serious threat to these forests is posed by coastal development, accidental fires, and in the Eastern Cape also by mining of heavy minerals from the coastal dunes (Von Maltitz et al. 2003). *Encephalartos altensteinii,* occurring in the Eastern Cape, is listed as vulnerable.

Remarks Southern Coastal Forests can be viewed as an impoverished form of Northern Coastal Forests. They show features of interesting biogeographic and floristic transitions between forests of subtropical and afrotemperate provenience and character (see also Phillipson & Russell 1978).

References Taylor (1961), Phillipson & Russell (1978), Burns (1986), Acocks (1988), Cowling et al. (1988), Lubke & Strong (1988), Knight (1989), McKenzie et al. (1990), Cooper & Swart (1992), Von Maltitz et al. (2003), Geldenhuys & Mucina (2006).

FOz 7 Northern Coastal Forest

Coast Forest & Psammophilous Bush (Bews 1920). Coastal Dune Forest & Coast Lowland Forest (Edwards 1967). Dune Forest & Undifferentiated Lowland Forest (Moll & White 1978). Tongaland-Pondoland Undifferentiated Forest p.p. (White 1983). Typical Coastal-belt Forest (Acocks 1988). Typical Coast Lowland Forest (Bartholomew 1989). Mozambique Coastal Plain Forest (MacDevette et al. 1989). Dune Forest (Cooper & Swart 1992). KwaZulu-Natal Coastal Forest and KwaZulu-Natal Dune Forest (Von Maltitz et al. 2003).

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Figure 12.16 FOz 7 Northern Coastal Forest: Interior of a scarp forest with *Strelitzia nicolai* in the Vernon Crookes Nature Reserve near Scottburgh (KwaZulu-Natal).

Distribution KwaZulu-Natal and (to a very small extent) Eastern Cape Province: Especially along the seaboards of Indian Ocean of KwaZulu-Natal Province and particularly well-developed in Maputaland. Few patches of the dune forest also occur on the Wild Coast of Transkei (Eastern Cape Province). Beyond South Africa these forests occur throughout the Mozambican seaboard as far as southern Tanzania. At low altitudes, from about 10 to 150 m.

Vegetation & Landscape Features Species-rich, tall/medium-height subtropical coastal forests occur on coastal (rolling) plains and stabilised coastal dunes. Forests of the coastal plains are dominated by *Drypetes natalensis*, *Englerophytum natalense*, *Albizia adianthifolia*, *Diospyros inhacaensis* etc. The low-tree and shrubby understoreys are species-rich and comprise many taxa of (sub)tropical provenience. On dunes, these forests have well-developed tree, shrub and herb layers. *Mimusops caffra*, *Sideroxylon inerme*, *Dovyalis longispina*, *Acacia kosiensis* and *Psydrax obovata* subsp. *obovata* are the most common constituents of the tree layer. *Brachylaena discolor* var. *discolor*, *Chrysanthemoides monilifera* subsp. *rotundata*, *Carissa bispinosa* subsp. *bispinosa*, *Euclea natalensis*, *E. racemosa*, *Eugenia capensis*, *Gymnosporia nemorosa*, *Kraussia floribunda*, *Peddiea africana*, *Strelitzia nicolai* and *Dracaena aletriformis* are frequent in the understorey. The herb layer usually contains by *Asystasia gangetica*, *Isoglossa woodii*, *Microsorum scolopendria*, *Zamioculcas zamiifolia* and *Oplismenus hirtellus*. Herbaceous

vines and woody climbers (*Acacia kraussiana*, *Artabotrys monteiroae*, *Dalbergia armata*, *Landolphia kirkii*, *Monanthotaxis caffra*, *Rhoicissus tomentosa*, *Rhus nebulosa*, *Scutia myrtina*, *Uvaria caffra*, *Gloriosa superba* etc.) are important structural determinants in these forests.

Geology & Soils Well-developed sandy-loamy soils on sedimentary rocks of the Karoo Supergroup and Jurassic intrusive dolerites (in places) as well as on Holocene marine sediments. Forming stabilised sandy dune systems, mostly younger than 10 000 years and still in the process of sedimentation.

Important Taxa Tall Trees: *Albizia adianthifolia* (d), *Drypetes reticulata* (d), *Mimusops caffra* (d), *Psydrax obovata* subsp. *obovata* (d), *Sideroxylon inerme* (d), *Trichilia emetica*, *Vepris lanceolata*. Small Trees: *Brachylaena discolor* subsp. *discolor* (d), *Buxus natalensis* (d), *Cavacoa aurea* (d), *Englerophytum natalense* (d), *Erythroxylum emarginatum* (d), *Eugenia capensis* (d), *Gymnosporia nemorosa* (d), *Kraussia floribunda* (d), *Peddiea africana* (d), *Rhus nebulosa* (d), *Strychnos henningsii* (d), *Acokanthera oblongifolia*, *Callichilia orientalis*, *Deinbollia oblongifolia*, *Dovyalis rhamnoides*, *Euclea natalensis*, *E. racemosa*, *Scutia myrtina*, *Strychnos decussata*, *Tapura fischeri*, *Teclea gerrardii*, *Turraea floribunda*, *Xylotheca kraussiana*. Woody Climbers: *Acacia kraussiana* (d), *Rhoicissus tomentosa* (d), *Dalbergia armata*, *Monanthotaxis caffra*, *Uvaria caffra*. Herbaceous Climber: *Gloriosa superba*. Tall Shrubs: *Carissa bispinosa* subsp. *bispinosa*, *Hyperacanthus amoenus*, *Putterlickia verrucosa*. Low Shrub: *Chrysanthemoides monilifera* subsp. *rotundata*. Soft Shrub: *Isoglossa woodii* (d). Megaherbs: *Dracaena aletriformis* (d), *Strelitzia nicolai* (d). Herbs: *Achyranthes aspera* (d), *Asystasia gangetica* (d), *Laportea peduncularis* (d). Geophytic Herb: *Microsorum scolopendria* (d). Graminoids: *Cyperus albostriatus* (d), *Oplismenus hirtellus* (d).

Biogeographically Important Taxa ([M]Maputaland endemic, [S]Southern distribution limit) Tall Trees: *Celtis gomphophylla*[S] (d), *Chrysophyllum viridifolium*[S] (d), *Diospyros inhacaensis*[S] (d), *Drypetes natalensis*[S] (d), *Cola natalensis*[S], *Inhambanella henriquesii*[S], *Manilkara concolor*[S]. Small Trees: *Coffea racemosa*[S] (d), *Dovyalis longispina*[S] (d), *Artabotrys monteiroae*[S], *Encephalartos ferox*[M], *Erythrococca berberidea*[S], *Pancovia golungensis*[S]. Tall Shrubs: *Haplocoelum foliolosum* subsp. *mombasense*[S], *Landolphia kirkii*[S].

Endemic Taxon Small Tree: *Acacia kosiensis* (d).

Conservation Least threatened in general, but still under threat on coastal dunes of KwaZulu-Natal (due to mining). Target 43%. About 68% statutorily conserved in Manguzi, Greater St Lucia Wetland Park, Maphelana, Dukuduku, Sodwana Bay, Richards Bay, Umlalazi, Enseleni, Amathigulu, Harold Johnson, Hawaan, Umhlanga Lagoon, Kenneth Stainbank, Impisini, Skyline, Frederika, Mpenjati Nature Reserves, mostly under Ezemvelo KZN Wildlife magement. The original extent of these forests has been diminished by agriculture (mainly sugar cane and fruit gardens), timber plantations, urban sprawl and tourism-oriented development on the KwaZulu-Natal coast. The current threats count (besides the ongoing coastal development pressures) also illegal clearing of the forest and turning it into lots for small-scale agriculture (Von Maltitz et al. 2003). Coastal dunes are being prospected and exploited for heavy metals—some companies are, however, actively engaged in dune forest regeneration programmes (Van Aarde & Wassenaar 1999). These subtropical forests are sensitive to alien plant invasion, and invaders such as *Chromolaena odorata*, species of *Pereskia* and *Acacia* are posing serious threats. Maputaland endemic *Encephalartos ferox* is listed as vulnerable.

Remarks However, many tropical species reach their southern distribution here. Von Maltitz et al. (2003) classified these forests into two Forest Types, namely the KwaZulu-Natal Coastal Forests (plains) and KwaZulu-Natal Dune Forests. The Manguzi Forest (near KaNgwanase in Maputaland) and some forest in the False Bay area of St Lucia show transitional features towards Sand Forest (Kirkwood & Midgley 1999).

References Bews (1920), Breen (1971), Venter (1976), Wager (1976), Weisser (1978, 1980, 1987), Ward (1980), MacDevette (1987, 1989, 1993), MacDevette & Gordon (1989a, b), MacDevette & MacDevette (1989), MacDevette et al. (1989), Cooper & Swart (1992), Weisser et al. (1992), Van Wyk & Everard (1992), Van Wyk et al. (1996), Von Maltitz et al. (1996, 2003), Lubbe (1997), Kirkwood & Midgley (1999), Van Aarde & Wassenaar (1999), Geldenhuys & Mucina (2006).

FOz 8 Sand Forest

Licuati Forest (Myre 1964). *Baphia massaiensis–Guibourtia conjugata* thicket (Van Rooyen et al. 1981). Tropical Dry Forests (MacDevette et al. 1989). Sand Forest (Low & Rebelo 1996). Licuati Sand Forest (Von Maltitz et al. 2003).

Distribution KwaZulu-Natal Province and Mozambique: Occurring in a broad and highly fragmented belt in South Africa from False Bay Park (Greater St Lucia Wetland Park) in the south to the national border with Mozambique (Tembe Elephant Park and Ndumo Game Reserve). The main distribution of this forest is in Maputaland, where still reasonably extensive patches of this forest can be encountered. Special thicket communities, floristically very close to the Maputaland sand forest, are found in the northern part of the Kruger National Park—here imbedded within Nwambyia and Pumbe sandvelds. At low altitudes between 20 and 160 m, with about half of the area between 100 and 120 m.

Vegetation & Landscape Features Dense thickets of 5–6 m ('short forest' of Matthews et al. 2001) up to tall forests

W.S. Matthews

Figure 12.17 FOz 8 Sand Forest: Aerial view of patches of sand forest in Maputaland (KwaZulu-Natal) surrounded by short savanna grasslands.

with the canopy reaching 15 m ('tall forest' of Matthews et al. 2001), with well-developed shrub layer and very poorly developed ground layer. The dominant trees are *Cleistanthus schlechteri*, *Dialium schlechteri* and emergent *Newtonia hildebrandtii* in Maputaland, whereas *Baphia massaiensis* subsp. *obovata*, *Cleistanthus schlechteri* and *Guibourtia conjugata* are most conspicuous in the tree layer in the Nwambyia and Pumbe regions. The shrub layer is dominated by *Croton pseudopulchellus*, *Cola greenwayi*, *Pteleopsis myrtifolia*, *Psydrax locuples*, *Drypetes arguta* and the woody climber *Uvaria lucida*. The most conspicuous graminoid in the herb layer is *Eragrostis moggii*. Epiphytic orchids and lichens festoon the tall trees.

Geology & Soils Grey to orange-brown (Maputaland), and dull brown/red-brown (Kruger National Park), deep arenosols and dystric (strongly leached) regosols; soils contain very little clay and are acidic. In Maputaland these soils develop on ancient (up to 3 myr old; Ndumo Hill cordon is up 5 myr old) mega-dune systems (crests, slopes and rarely also inter-dune depressions) of the Maputaland and Zululand Groups.

Important Taxa ([M]In South Africa only in Maputaland, [K]Only in northern Kruger National Park) Tall Trees: *Balanites maughamii* (d), *Cleistanthus schlechteri* (d), *Cola greenwayi*[M] (d), *Dialium schlechteri*[M] (d), *Drypetes arguta*[M] (d), *Guibourtia conjugata*[K] (d), *Newtonia hildebrandtii* (d), *Pteleopsis myrtifolia* (d), *Drypetes mossambicensis*[K], *D. natalensis*[M], *Lagynias lasiantha*, *Lannea antiscorbutica*[M], *Pterocarpus lucens* subsp. *antunesii*[K], *Suregada zanzibariensis*[M], *Xeroderris stuhlmannii*[K]. Small Trees: *Baphia massaiensis* subsp. *obovata*[K] (d), *Hymenocardia ulmoides* (d), *Wrightia natalensis* (d), *Alchornea laxiflora*[K], *Brachylaena huillensis*, *Callichilia orientalis*[M], *Cassipourea mossambicensis*[M], *Cavacoa aurea*[M], *Coffea racemosa*[M], *Dalbergia nitidula*[K], *Heinsia crinita*[K], *Hexalobus monopetalus*[K], *Hugonia orientalis*[K], *Markhamia zanzibarica*[K], *Monodora junodii* var. *junodii*, *Strychnos madagascariensis*, *Toddaliopsis bremekampii*, *Xylotheca kraussiana*. Woody Climbers: *Uvaria lucida* (d), *Prionostemma delagoensis* var. *delagoensis*[M], *Sclerochiton apiculatus*[M], *Uvaria gracilipes*[K]. Tall Shrubs: *Croton pseudopulchellus* (d), *C. steenkampianus* (d), *Canthium setiflorum* subsp. *setiflorum*, *Coptosperma zygoon*[K], *Erythrococca menyharthii*[K], *Haplocoelum foliolosum* subsp. *mombasense*[M], *Pavetta catophylla*. Low Shrubs: *Tricalysia junodii* var. *junodii*, *Warneckea sousae*. Herb: *Aneilema arenicola*[M]. Succulent Herb: *Crassula maputensis*[M]. Graminoids: *Eragrostis moggii*[M] (d), *Panicum laticomum*.

Endemic Taxa ([M]In South Africa only in Maputaland, [K]Only in northern Kruger National Park) Tall Tree: *Erythrophleum lasianthum*[M]. Small Trees: *Monodora junodii* var. *macrantha*[K], *Oxyanthus latifolius*[M]. Woody Climbers: *Combretum celastroides* subsp. *orientale*, *Schlechterina mitostemmatoides*[M], *Strophanthus luteolus*[M]. Tall Shrubs: *Gymnosporia oxycarpa*[K], *G. pubescens*, *Psydrax fragrantissima*[M], *Tricalysia delagoensis*[M]. Low Shrubs: *Leptactina delagoensis* subsp. *delagoensis*, *Salacia leptoclada*[M]. Geophytic Herb: *Bonatea lamprophylla*[M]. Graminoid: *Brachychloa schiemanniana*[M].

Conservation Critically endangered due to its vulverability and economic pressure. Target 100%. Some 42% statutorily conserved in Tembe Elephant Park, Sileza Nature Reserve, Ndumo and Mkhuze Game Reserves, Greater St Lucia Wetland Park, Kruger National Park and in private Phinda Resource Reserve. An unknown portion was lost through clearing for subsistence agriculture and grazing. Uncontrolled extraction of wood for fuel and woodcraft is a problem as is the high density of elephants in Tembe Elephant Park—the best preserved portion of the sand forest in South Africa.

Remarks This forest houses a large number of local Maputaland endemics (Matthews et al. 1999, 2001) and forms the core of the Maputaland Regional Centre of Endemism (Van Wyk & Smith 2001). Many other tropical elements have their southernmost distribution here and/or are found in South Africa exclusively here (Van Wyk & Smith 2001, Schmidt et al. 2002).

References Myre (1964), De Moor et al. (1977), Moll (1978), Van Rooyen (1978), Van Rooyen et al. (1981), Gertenbach (1983), Kirkwood & Midgley (1999), Matthews et al. (1999, 2001), Van Wyk & Smith (2001), Schmidt et al. (2002), Von Maltitz et al. (2003), Gaugris et al. (2004), Geldenhuys & Mucina (2006).

FOz 9 Ironwood Dry Forest

Androstachys johnsonii–Croton pseudopulchellus dry forest (Van Rooyen et al. 1981).

Distribution Limpopo Province: Northern part of the Kruger National Park in the Lebombo Mountains as well as in the surroundings of Punda Maria. Possibly also found in the Soutpansberg. Found at most mapped patches at altitudes between 280 and 580 m.

Vegetation & Landscape Features On moderate to steep mountain slopes (up to 22°), forming dense forests (sometimes called 'thicket') dominated by Lebombo Ironwood (*Androstachys johnsonii*), which may build a closed canopy reaching up to 10 m. *Croton pseudopulchellus* attains high densities in the understorey. The adjacent bushveld communities are often sharply demarcated from the forest (Van Rooyen et al. 1981).

Geology & Soil fine to medium-textured (dark red-brown to brown-red) sand to sandy- loamy soil derived from Soutpansberg Group sandstone and quartzite, Karoo Supergroup sandstone as well as Lebombo Group rhyolites and the Cretaceous Malvernia Formation sandstones. Rocks cover 60% of the surface and soil depth ranges from 100–250 mm. pH of soil spans 4.8–8.3 and there is a moderate concentration of soluble salts or the soil is strongly leached in places (Van Rooyen et al. 1981).

Important Taxa (*Also occurring in FOz 8 Sand Forest) Tall Trees: *Androstachys johnsonii* (d), *Entandrophragma caudatum**. Small Trees: *Alchornea laxiflora**, *Boscia albitrunca*, *Cassia abbreviata* subsp. *beareana*, *Commiphora tenuipetiolata*, *Croton gratissimus*, *Euphorbia espinosa*, *Hymenodictyon parvifolium*, *Monodora junodii* var. *junodii**, *Pouzolzia mixta*, *Vitex ferruginea**. Succulent Tree: *Euphorbia confinalis*. Woody Climbers: *Combretum paniculatum*, *Strophanthus kombe**. Herbaceous Climber: *Ipomoea magnusiana*. Tall Shrubs: *Croton pseudopulchellus** (d), *C. madandensis*, *Dombeya kirkii*, *Phyllanthus reticulatus*. Low Shrubs: *Asparagus setaceus*, *Hibiscus micranthus*, *Phyllanthus pinnatus*. Herbs: *Achyranthes aspera* (d), *Commelina benghalensis* (d), *Selaginella dregei* (d), *Blainvillea gayana*, *Blepharis maderaspatensis*, *Celosia trigyna*, *Cleome monophylla*, *Corchorus longipedunculatus*, *Monechma debile*, *Pupalia lappacea*, *Spermacoce senensis*, *Triumfetta pentandra*, *Xerophyta equisetoides*, *X. humilis*. Geophytic Herbs: *Cheilanthes viridis*, *Pellaea calomelanos*. Graminoids: *Aristida congesta* (d), *Panicum maximum* (d), *Brachiaria deflexa*, *Danthoniopsis pruinosa*, *Digitaria eriantha*, *Enteropogon macrostachyus*, *Leptocarydion vulpiastrum*, *Setaria pumila*, *S. sagittifolia*, *Sporobolus panicoides*.

Endemic Taxon Tall Shrub: *Pavetta tshikondeni*.

Conservation Target 100%. About 78% (of the mapped patches) statutorily conserved in Kruger National Park and Mlawula Nature Reserve. Only a very small portion has been transformed.

Remarks Despite early recognition of this vegetation as 'dry forest' (Van Rooyen 1978, Van Rooyen et al. 1981), forest managers have, surprisingly, persisted in considering it a 'thicket' form of savanna. The Punda Maria ironwood forests are more mesic than those of the Lebombo (Gertenbach 1983). More extensive and still taller forest stands of this vegetation type can be found in neighbouring Mozambique and southern Zimbabwe. Due to lack of data we have not mapped this forest type in the Soutpansberg range.

References Van Wyk (1973), Van Rooyen (1978), Van Rooyen et al. (1981), Coetzee (1983), Gertenbach (1983), Von Maltitz et al. (2003), Geldenhuys & Mucina (2006).

Azonal Units

FOa 1 Lowveld Riverine Forest

Gallery Forest (*sensu auct.*). Fringing Forest (Moll & White 1978). Riverine Forest (Cooper 1985). Lowveld Riverine Forest (Von Maltitz et al. 2003).

Distribution KwaZulu-Natal, Mpumalanga and Limpopo Provinces (as well as in Swaziland and other countries neighbouring on South Africa): Broad river alluvia of Zululand (Hluhluwe, middle reaches of Phongolo), Maputaland (Mkuze, lower reaches of Phongolo, Usutu) and numerous rivers draining the northern provinces of South Africa (Limpopo, Luvuvhu, Phongolo, Shingwedzi, Letaba, Olifants, Timbavati, Sabie, Crocodile). At low altitudes, from about 20 to 320 m.

Vegetation & Landscape Features Tall forests fringing larger rivers (gallery forests) and water pans. When dominated by *Ficus sycomorus* or *Diospyros mespiliformis* (alluvial sediments along major rivers), these forests are dense and tall, structured into several tree layers and with a well-developed dense shrub layer.

Geology, Soils & Hydrology Recent alluvial deposits with deep, fine-textured soils (e.g. Dundee soil form). Subject to frequent flooding and occasionally to very heavy flood spells.

Important Taxa Tall Trees: *Acacia robusta* subsp. *clavigera* (d), *Breonadia salicina* (d), *Diospyros mespiliformis* (d), *Faidherbia albida* (d), *Ficus sycomorus* (d), *Kigelia africana* (d), *Berchemia discolor*, *Combretum erythrophyllum*, *C. imberbe*, *Ekebergia capensis*, *Philenoptera violacea*, *Rauvolfia caffra*, *Spirostachys africana*, *Syzygium guineense*, *Trichilia emetica*, *Xanthocercis zambesiaca*. Small Trees: *Combretum hereroense*, *Croton megalobotrys*, *Hyphaene coriacea*, *Nuxia oppositifolia*, *Phoenix reclinata*, *Vernonia colorata*. Tall Shrubs: *Abutilon angulatum*, *Acacia schweinfurthii*, *Ficus capreifolia*. Soft Shrub: *Hypoestes aristata*. Herb: *Achyranthes aspera* (d). Graminoids: *Digitaria eriantha* (d), *Panicum maximum* (d), *Echinochloa pyramidalis*, *Eriochloa meyeriana*, *Panicum coloratum*, *Phragmites mauritianus*, *Setaria incrassata*, *S. sphacelata*, *Sporobolus consimilis*.

Conservation Critically endangered. Target 100%. Half statutorily conserved in Kruger and Mapungubwe National Parks, Greater St Lucia Wetland Park, Ndumo and Mkhuze Game Reserves (here the Fig Forest is one of the prime examples), Mlawula and Blyde River Canyon National Park in South Africa, Royal Hlane Game Sanctuary in Swaziland as well as in a number of private game and nature reserves east and south of the Kruger National Park, Selati Game Reserve, Limpopo Valley Wildlife Utilisation Area etc. Unknown portion has been irreversibly transformed by clearing for cultivation. Aliens such as *Melia azedarach, Lantana camara, Psidium guajava, Chromolaena odorata, Caesalpinia decapetala* are serious invaders in places. Agricultural malpractices upstream, building of dams and excessive water extraction for agriculture and mining as well as local exploitation for timber and non-timber forest products are serious threats to this vegetation (Von Maltitz et al. 2003).

Remarks Low (as compared to forests) riparian thickets found along rivers in Lowveld and Central Bushveld feature as part of the AZa 7 Subtropical Alluvial Vegetation.

References De Moor et al. (1977), Moll (1978), Van Rooyen (1978), Van Rooyen et al. (1981), Gertenbach (1983), Whateley & Porter (1983), Cooper (1985), Bredenkamp & Deutschländer (1995), Von Maltitz et al. (2003), Geldenhuys & Mucina (2006).

FOa 2 Swamp Forest

Hygrophilous Bush, Waterboom Associes & *Barringtonia* Associes (Bews 1920). Hygrophilous Forest (Weisser 1978). Swamp Forest (Von Maltitz et al. 2003).

Distribution KwaZulu-Natal and Eastern Cape Provinces: In pockets and narrow ribbons extending in a narrow belt along the Indian Ocean coast from Maputaland as far south as Port Grosvenor in Pondoland. Swamp Forests reach lower latitudes than Mangrove Forests, which suggests that they are climatically more limited than the mangroves. At low altitude, mainly between 20 and 60 m.

Vegetation & Landscape Features 12–15 m tall forests with two main strata (canopy and shrub layers). The dominating trees include *Ficus trichopoda*, *Barringtonia racemosa*, *Casearia gladiiformis*, *Cassipourea gummiflua*, *Syzygium cordatum*, *Phoenix reclinata* and *Raphia australis*. Understorey is poorly developed. Some ferns such as *Microsorum punctatum* and *Nephrolepis biserrata* are of importance and orchids (*Eulophia horsfallii*) occur frequently.

Geology, Soils & Hydrology Very fine, muddy, waterlogged soil, with organic humus, a peat-like layer and anoxic conditions. The St Lucia swamp forests are

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Figure 12.18 FOa 1 Lowveld Riverine Forest: Riparian forests with *Acacia gerrardii* on the Crocodile River near Lephalale (Limpopo Province).

found on sand, sandy loam or loamy sand with a moderate to high status (7–17%) of organic matter. The soil is acidic, pH range 2.5–6 (mean 3–4.5), and calcium and magnesium concentrations can be high. Impeded drainage and poor aeration characterise soil forms such as Sterkspruit, Valsrivier and Katspruit (Nyalazi area) or Fernwood and Champagne (Eastern Shores State Forest in the St Lucia area). Water is acidic to alkaline and mineral-rich with high calcium, magnesium and conductivity values. Water tables were found to fluctuate from the surface to a depth of 600 mm (Wessels 1991b).

J.C. Manning

Figure 12.19 FOa 2 Swamp Forest: *Scadoxus multiflorus* subsp. *katherinae* (Amaryllidaceae) flowering in the understorey of swamp forest near Munster on the KwaZulu-Natal south coast.

Important Taxa Tall Trees: *Barringtonia racemosa* (d), *Ficus trichopoda* (d), *Macaranga capensis* (d), *Rauvolfia caffra* (d), *Schefflera umbellifera* (d), *Shirakiopsis elliptica* (d), *Syzygium cordatum* (d), *Ficus lutea*. Small Trees: *Allophylus dregeanus* (d), *Bridelia micrantha* (d), *Cassipourea gummiflua* (d), *Morella serrata* (d), *Phoenix reclinata* (d), *Sclerocroton integerrimum*. Woody Climber: *Adenopodia spicata*. Herbaceous Climbers: *Stenochlaena tenuifolia* (d), *Ipomoea indica*, *I. mauritiana*. Tall Shrubs: *Burchellia bubalina* (d), *Psychotria capensis* (d), *Tarenna pavettoides* subsp. *pavettoides* (d), *Hibiscus tiliaceus* (d). Geophytic Herbs: *Eulophia horsfallii* (d), *Microsorum punctatum* (d), *Nephrolepis biserrata* (d). Graminoid: *Scleria angusta* (d).

L. Mucina

Figure 12.20 FOa 2 Swamp Forest: Interior of a swamp forest with *Ficus trichopoda* near Mtunzini (KwaZulu-Natal).

Biogeographically Important Taxa (all at southern distribution limit) Tall Trees: *Voacanga thouarsii* (d), *Scolopia stolzii*. Tall Shrub: *Ficus verruculosa*. Megaherb: *Dracaena mannii*.

Endemic Taxon Tall Tree: *Raphia australis* (d).

Conservation Critically endangered. Target 100%. Some 66% statutorily conserved in Greater St Lucia Wetland Park, Maphelana, Dududuku, Raphia Palms and Umlalazi Nature Reserves. Unknown portion has been already transformed either for plantations or by illegal clearing for making fruit and vegetable gardens. Especially the swamp forests in the Kosi Bay area are disappearing with alarming speed. *Chromolaena odorata, Lantana camara* and *Pereskia* species are common invaders in disturbed swamp forests. Change in local hydro-geological conditions poses another serious threat to this fragile forest ecosystem (Von Maltitz et al. 2003).

Remarks Swamp Forests have a strong tropical link and reach their southernmost distribution limit in South Africa. The endemic *Raphia australis* is limited to Maputaland and forms an intriguing forest in the Kosi Bay lagoon system. It also forms a planted grove in Mtunzini (KwaZulu-Natal).

References Bews (1920), Moll (1972), Venter (1972, 1976), Moll & White (1978), Weisser (1978, 1987), Ward (1980), Weisser & Ward (1982), Wessels (1991a, b), Weisser et al. (1992), Lubbe (1997), Von Maltitz et al. (2003), Geldenhuys & Mucina (2006).

FOa 3 Mangrove Forest

Distribution KwaZulu-Natal and Eastern Cape Provinces: Coastal lagoons and estuaries of Transkei as far south as Kobonqaba Estuary—the highest latitude with extant mangroves in the world (Moll & Werger 1978, Ward & Bunyard 1992) as far north as KwaZulu-Natal/Mozambique border (Kosi Bay estuary) and beyond to Mozambique and further northwards to tropical East Africa. At very low altitudes around sea level.

Vegetation & Landscape Features Species-poor and often monospecific, low and dense forests of mangroves (and fring-

L. Mucina

Figure 12.21 FOa 3 Mangrove Forest: Interior of *Avicennia marina* mangrove in St Lucia Estuary with tracks of a hippo (*Hippopotamus amphibius*).

L. Mucina

Figure 12.22 FOa 3 Mangrove Forest: *Avicennia marina* shrub on the edge of a mangrove forest in Umlalazi Nature Reserve near Mtunzini (KwaZulu-Natal).

ing thickets of *Hibiscus tiliaceus* and *Acrostichum aureum*) in tidal zones of coastal lagoons and estuaries.

Geology, Soils & Hydrology Mangroves occur between mean sea level and mean high-water spring tide level in sheltered estuaries on tidal flats built by recent sediments caused by accretion of river-borne sediments, to which material brought in from the sea with the rising tide is added; the soils are poorly drained, saline, anoxic, fine-grained and rich in organic content (coming from decomposing plant debris).

Important Taxa Small Trees: *Avicennia marina* (d), *Bruguiera gymnorrhiza* (d), *Ceriops tagal*, *Lumnitzera racemosa*, *Rhizophora mucronata*, *Xylocarpus granatum*. Tall Shrub: *Hibiscus tiliaceus* (d). Geophytic Herb: *Acrostichum aureum* (d).

Conservation Critically endangered. Target 100%. About 72% statutorily conserved in Greater St Lucia Wetland Park, Richards Bay, Beachwood Mangroves and Umlalazi Nature Reserves. Much of the original extent of mangrove was lost in South Africa through harbour development (Richards Bay and Durban), clearing for development (Durban) or they became degraded through unfavourable agricultural practices upstream of the rivers feeding into the estuaries.

Remarks Mangrove Forests are imbedded within the Indian Ocean Coastal Belt (see also Chapter 11) where they are found to form a vegetation complex with AZe 3 Subtropical Estuarine Salt Marshes. According to Moll & Werger (1978), the South African mangroves belong to the group of 'East Coast Mangroves' (referring to eastern coasts of Africa).

References Berjak et al. (1995), Moll & Werger (1978), Ward (1980), Ward & Steinke (1982), Ward et al. (1986), Weisser (1987), MacDevette et al. (1989), Cooper & Swart (1992), Ward & Bunyard (1992), Roberts (1993), Steinke (1995), Colloty et al. (2002), Von Maltitz et al. (2003), Geldenhuys & Mucina (2006).

12. Credits

The text of descriptions of all units was provided by L. Mucina. The species lists were compiled by L. Mucina and C.J. Geldenhuys (extracted from so far unpublished report by Von Maltitz et al. 2003, wherein the species lists were also created by the senior authors of this chapter). C.J. Geldenhuys wrote the extensive introductory text to the chapter (sections 1 to 10) to which L. Mucina contributed several additions (especially to section 4). L. Mucina has further contributed to the delimitation of several forest patches in the Western Cape, Eastern Cape, KwaZulu-Natal and Free State Provinces. C.J. Geldenhuys selected the quotation on the opening page. G.P. von Maltitz contributed to this chapter by providing unpublished material, leading to formulation of the sections on Conservation in the descriptions of vegetation units. M.C. Lötter and L. Dobson have contributed to improvement of the mapped forest coverage in Mpumalanga and in Swaziland, respectively. M.C. Lötter and W.S. Matthews

have contributed to the descriptions of FOz 4 and FOz 8, respectively, and provided further valuable comments on other parts of the text and the mapped forest coverage. D.I.W. Euston-Brown contributed an unpublished coverage of milkwood forests in the Overberg region (FOz 6) and B. McKenzie helped mapping forest patches in the Western Cape (FOz 1). M.C. Rutherford and L.W. Powrie have provided environmental data used in the descriptions of the vegetation units. M.C. Rutherford was also instrumental in conceptual issues concerning units FOz 1, FOz 2 and FOa 1 as well as shaping the final appearance of the forest patches on the map. L.W. Powrie and L. Mucina jointly produced Figures 12.2 and 12.3. M.C Rutherford and L.W. Powrie supplied climate diagrams (Figure 12.8). M. Rouget and others within the Directorate of Biodiversity Programmes, Policy and Planning of SANBI provided the quantitative information for each vegetation unit on various conservation issues.

The original Forest Biome Project Map (Anonymous 1987) was provided by the CSIR, Pretoria through the project on classification of indigenous forests (see Von Maltitz et al. 2003 for a public-domain report). In KwaZulu-Natal this coverage was replaced by new data which resulted from a forest mapping project steered by Ezemvelo KZN Wildlife. In Mpumalanga a part of the original Forest Biome Project Map was replaced by coverage featured in an unpublished report by Emery et al. (2002). We express our gratitude to DWAF, CSIR, Ezemvelo KZN Wildlife and Mpumalanga Parks Board for providing these sources. J.E. Burrows kindly commented on FOz 4 and suggested corrections to the species list. W.S. Matthews and J.C. Manning contributed some photographs. R.A. Ward kindly collated the geological terminology. J. Gilliatt redrew Figure 12.4.

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with contributions by

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1. Introduction: Concepts Related to Zonality of Vegetation

Water, salt and processes linked to concentration of both are the major controls of the creation, maintenance and development of peculiar habitats. Habitats, formed in and around flowing and stagnant freshwater bodies experience waterlogging (seasonal or permanent) and flooding (regular, irregular or catastrophic), leading to formation of special soil forms. Habitats with high levels of salt concentration form a highly stressed environment for most plants and often markedly affect the composition of plant communities. Invariably, both waterlogged and salt-laden habitats appear as 'special', deviating strongly from the typical surrounding zonal vegetation. They are considered to be of azonal character.

Azonal vegetation has long been an orphan of vegetation mapping in South Africa and overseas. Its enormous complexity is usually little known, and its limited extent (small size of patches) poses a challenge to mapping at scales smaller than 1:50 000.

In countries such as South Africa, where broad-scale vegetation complexes (or in other words vegetation on supra-habitat level) have always been the major focus, the concept of azonality remained largely unknown, denied or at best recognised but unexplored. A notable exception is the study of Campbell (1985) on classification of mountain fynbos of the Cape. He used the term 'azonality' explicitly to recognise various groups of communities within his 'Restioid Fynbos'. Azonal Restioid Fynbos according to Campbell (1985) is limited owing to waterlogging or to excessive drainage or as a consequence of a combination of these two habitat conditions. In his ground-breaking monograph on vegetation of the upper Orange (Gariep) River Valley, Werger (1980), who was instrumental in importing European ways of doing vegetation science to South Africa, speaks about 'minor communities', obviously referring to those of azonal nature. Mention of only these two sources does not necessarily imply that other students of South African vegetation did not sample azonal vegetation. However, they came short of defining the relationship of such vegetation to zonal vegetation patterns, neglected the question of intrazonality and, most importantly, failed to feature azonal (and intrazonal) vegetation on vegetation maps of the country. Admittedly, this was also due to the physical limitation imposed by the small scale of the maps (1:1 500 000 in Acocks 1953 and 1:1 850 000 in Low & Rebelo 1996) concomitant with the then more limited state of knowledge of the spatial variation of vegetation in South Africa. There was an attempt at continued adherence to the practice of not mixing different spatial scales on the same map. It is one of the major purposes of the National Vegetation Map to give the azonal vegetation of the region (with its 23 inland and 11 coastal azonal vegetation units) desired coverage for the first time.

All concepts related to zonality of vegetation go back to the fundamental work of Heinrich Walter. In simple terms, he used the term *zonal* to refer to the vegetation typical of climatic zones. Such vegetation forms an integrated part of biomes (for recent definitions see Mucina 2000 and the Chapter on Biomes and Bioregions in this book) or, more precisely, of 'zonobiomes' in Walter's terminology (Walter 1964, 1973, Walter & Box 1976, Walter & Breckle 1991). Hence, it is a complex of macroclimate characteristics, which exert control over structure and dynamics of the zonal vegetation. The typical soils occurring within such (climate-defined) zones are also considered zonal. The zonal vegetation can occur as *extrazonal* in specialised habitats outside the climatic zones (where this kind of vegetation is considered to be of zonal nature).

In *azonal* vegetation *sensu lato*, on the other hand, special substrate (special soil types or bedrocks) and/or hydrogeological conditions (waterlogging, flooding, tidal influence) exert an overriding influence on floristic composition, structure and dynamics over macroclimate. (Vegetation of heavily disturbed and man-made habitats, termed anthropogenic, synanthropic, ruderal or agrestal, falls within this broadly conceived concept of azonality as well.) If such vegetation occurs exclusively within a climatic (and vegetation or biome) zone, then it is considered to be *intrazonal*. Where such vegetation occurs irrespective of climatic and vegetation zones, we use the term *azonal* vegetation *sensu stricto*.

An example of typical zonal vegetation would be proteoid sandstone fynbos, granite asteraceous renosterveld etc. occurring within the zone called the Fynbos Biome. Hence vegetation units such as FFs 9 Peninsula Sandstone Fynbos, FFg 2 Boland Granite Fynbos, FRs 9 Swartland Shale Renosterveld and the like are considered as zonal. The vegetation units such as AZf 2 Cape Vernal Pools or AZi 9 Cape Inland Salt Pans are typical intrazonal units. Structure and dynamics of both are determined by either waterlogging or accumulation of salt (hence by special hydrogeological or pedological conditions), and equally importantly—both embedded within the zone of the Fynbos Biome and experiencing similar climatic traits of that particular climatic-vegetation zone. AZf 6 Subtropical Freshwater Wetlands, on the other hand, occur across the zones of the Savanna Biome, Indian Ocean Coastal Belt and Albany Thicket Biome, and hence qualify as an azonal unit in the narrow sense (Table 13.1). The climate diagrams of the particular regions where the azonal vegetation units have been mapped (Figure 13.2) reflect the patterns of intrazonality (where the form of the climate diagram follows the basic patterns of the surrounding zone) as well as azonality (characterised by a lack of distinct pattern due to a pooling effect).

Although the concept of azonality did receive some marginal attention in South African vegetation-ecological literature in the past, the concept of intrazonality is entirely new to it. Undeniably, it is also a rather controversial issue as it is scale dependent, requiring definition of the system of zones. Therefore, for practical reasons we refrain from an attempt to distinguish clearly between intrazonal and azonal (*sensu stricto*) units. Because the concepts of azonal (*sensu lato*) units as defined in our map and in this chapter are narrowly defined both in habitat and regional terms, most of those units are actually intrazonal (Table 13.1).

We are well aware of the fact that the same concepts (azonality and intrazonality) can be applied to the forest vegetation. We have decided to feature both zonal and azonal forest vegetation within one chapter for conventional and practical purposes.

Table 13.1 Spatial link between the inland azonal vegetation units and surrounding biome, with reference to the zonality status of the units. IOCB: Indian Ocean Coastal Belt.

Vegetation Unit	Biome	Zonality
Freshwater Wetlands		
AZf 1 Cape Lowland Freshwater Wetlands	Fynbos	intrazonal
AZf 2 Cape Vernal Pools	Fynbos	intrazonal
AZf 3 Eastern Temperate Freshwater Wetlands	Grassland	intrazonal
AZf 4 Drakensberg Wetlands	Grassland	intrazonal
AZf 5 Lesotho Mires	Grassland	intrazonal
AZf 6 Subtropical Freshwater Wetlands	Savanna; Albany Thicket; IOCB	azonal
Alluvial Vegetation		
AZa 1 Fynbos Riparian Vegetation	Fynbos	intrazonal
AZa 2 Cape Lowland Alluvial Vegetation	Fynbos	intrazonal
AZa 3 Lower Gariep Alluvial Vegetation	Succulent Karoo	intrazonal
AZa 4 Upper Gariep Alluvial Vegetation	Grassland	intrazonal
AZa 5 Highveld Alluvial Vegetation	Grassland	intrazonal
AZa 6 Albany Alluvial Vegetation	Albany Thicket	intrazonal
AZa 7 Subtropical Alluvial Vegetation	Savanna; IOCB	azonal
Inland Saline Vegetation		
AZi 1 Namaqualand Riviere	Succulent Karoo	intrazonal
AZi 2 Namaqualand Salt Pans	Succulent Karoo	intrazonal
AZi 3 Southern Kalahari Mekgacha	Savanna	intrazonal
AZi 4 Southern Kalahari Salt Pans	Savanna	intrazonal
AZi 5 Bushmanland Vloere	Nama-Karoo	intrazonal
AZi 6 Southern Karoo Riviere	Nama-Karoo	intrazonal
AZi 7 Tanqua Wash Riviere	Succulent Karoo	intrazonal
AZi 8 Muscadel Riviere	Succulent Karoo	intrazonal
AZi 9 Cape Inland Salt Pans	Fynbos	intrazonal
AZi 10 Highveld Salt Pans	Grassland; Nama-Karoo	azonal
AZi 11 Subtropical Salt Pans	Savanna	intrazonal

2. Typology of Inland Azonal Vegetation in South Africa

Water, in conjunction with geology, soil, topography and climate, is responsible for the creation of remarkably many types of habitats. Water chemistry, temperature (and temporary changes in both) together with the amount of water (depth of water column), timing of occurrence (regular tides or irregular floods) and speed of its movement (discharge, flow and stagnation) are the major factors shaping the ecology of biotic communities occupying such habitats.

Noble & Hemens (1978) coined the first habitat-level system for southern African wetlands. Their original scheme has been modified (adding new categories and hierarchies to the system) in later publications (Breen & Begg 1989, Rogers 1995 and recently also Sieben et al. 2004; see Rogers 1997 for a comprehensive account). A simple vegetation/habitat system (from a pan-African point of view) was also suggested by Denny (1993). The habitat-level system adopted by the Ramsar Convention in Recommendation C.4.7 (Rev) of 199 (see also Cowan 1995c) is comprehensive and also includes categories of coastal wetlands, but does not yet enjoy broad general acceptance in South Africa.

On (sub)continental level there were several attempts to classify the surface of South(ern) Africa into wetland zones. Harrison (1959) attempted to subdivide the territory of South Africa, Lesotho and Swaziland into 13 'hydrobiological regions' based on types of rivers. Allanson et al. (1990) introduced a limnological system comprising five categories, such as Subtropical Coastal Peneplain, Southeastern Coastal Plain and Elevated Plateau, Australomontane, Temperate Acid Waters of the Western Cape and finally Arid West. Rogers (1995) suggested a system based on several 'determinants' such as topography (prevailing criterion), hydrology and nutrient regime to arrive at four broad groups, based on the 'broad morphology of the country' further subdivided into 26 regions. The latest attempt was made within a pan-African background when Thieme et al. (2005) suggested the subdivision of the region comprising South Africa, Lesotho and Swaziland into seven 'ecoregions' (representing four bioregions), such as 37-Drakensberg-Maloti Highlands, 36-Amatolo-Winterberg Highlands, 73-Southern Temperate Highveld, 77-Zambezian Lowland, 33-Cape Fold, 91-Southern Kalahari and 93-Western Orange. The classification and delineation into bioregions and ecoregions primarily followed fish distribution data.

Our classification approach follows multilayered criteria, the macro-ecological one (character of azonality and combination of azonality-driving ecological factors such as water and salt content) being the most important. According to this criterion, we distinguish, firstly, freshwater wetlands (along stagnant or slow-flowing waters) as different from, secondly, alluvial vegetation fringing water courses and undergoing dynamic change due to a periodic flood regime. The third class—the 'inland azonal vegetation'—comprises vegetation accompanying salt-laden intermittent rivers and salt pans. High concentration of salt in the environment (either soil or water or both) is the major ecological determinant of this vegetation complex. Further subdivision within these three categories follows biogeographical (hence floristic and floral-evolutionary) criteria and reflects the link between the azonal vegetation unit and its corresponding 'matrix' zonal vegetation (Table 13.1). A comparison of the spatial extent of the zonal and azonal vegetation identified only four units as truly azonal, hence occurring within more than one biome—three subtropical units and Highveld Salt Pans. The other vegetation units are intrazonal. The vegetation units recognised in this chapter can be classified with high certainty into four Rogers's (1995) regions (Table 13.2), with the notable exception of our subtropical units (AZf 6, AZa 7 and AZi 11) shared by three of the four broad groups; the subtropical wetland units naturally do not occur in the fourth group—the 'Mountain Wetlands'.

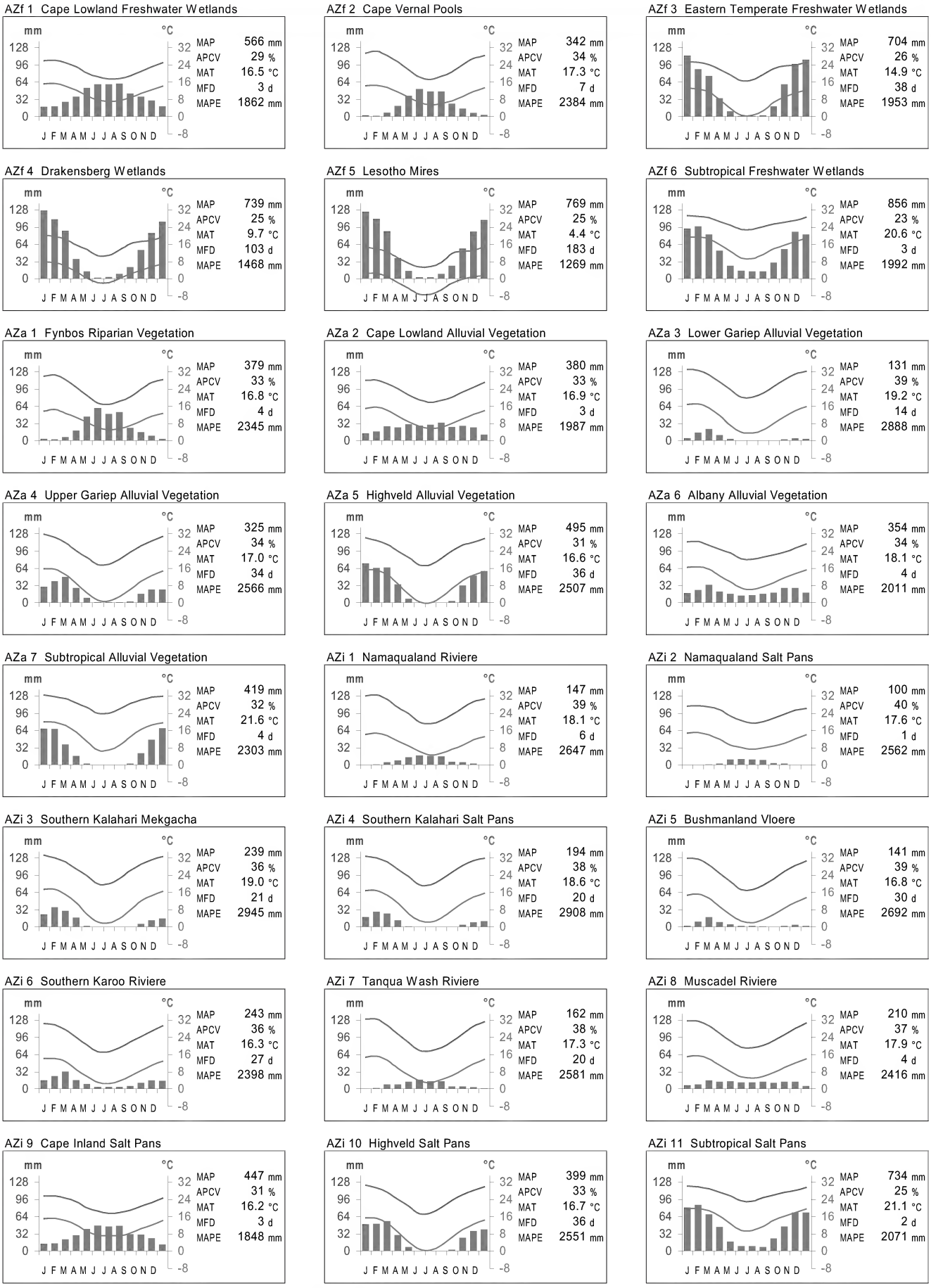

Figure 13.2 Climate diagrams of Inland Azonal Vegetation units. Blue bars show the median monthly precipitation. The upper and lower red lines show the mean daily maximum and minimum temperature respectively. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days (days when screen temperature was below 0°C); MAPE: Mean Annual Potential Evaporation.

Table 13.2 Correspondence between the Wetland Regions of Cowan (1995c) coded as C, S, M and P and the vegetation units as described in this Chapter (for the codes see the List of Vegetation Units) and combined into three groups, namely FW (Freshwater Wetlands), AV (Alluvial Vegetation) and ISV (Inland Saline Vegetation). The units given in bold are shared between Wetland Regions C, S and P, while the other units show exclusive links to a wetland region. N: data do not apply.

	FW	AV	ISV
C Coastal plain wetlands	**AZf 6**	**AZa 7**	**AZi 11**
S Coastal slope & rimland	**AZf 6**	**AZa 7**	**AZi 11**
	AZf 1	AZa 2	AZi 1
	AZf 2	AZa 3	AZi 2
		AZa 6	AZi 9
			AZi 6
			AZi 7
			AZi 8
M Mountain wetlands	AZf 4	AZa 1	N
	AZf 5		
P Plateau wetlands	**AZf 6**	**AZa 7**	**AZi 11**
	AZf 3	AZa 4	AZi 3
		AZa 5	AZi 4
			AZi 5
			AZi 10

3. Freshwater Wetlands, Alluvial and Inland Saline Vegetation

In this chapter we address the inland segment of the wetlands of southern Africa. Here we feature and classify (in floristic-biogeographical terms) the wetland vegetation of all freshwater wetlands (including vleis, marshes, mires, lakes, alluvia) and vegetation of land-locked salt-laden habitats (including salt pans and river channels of intermittent rivers in arid and semi-arid regions).

3.1 Freshwater Wetlands

Freshwater wetlands form a system of archipelagos of small and highly fragmented patches, embedded within all mainland biomes of South Africa. They are particularly common landscape features in regions with mean annual precipitation exceeding 500–600 mm (Figure 13.3). The floristic composition in the freshwater habitats underwent a series of ecological and evolutionary filters linking the azonal vegetation with its background zonal vegetation. The classification of the freshwater wetlands into vegetation units as applied in our map reflects this link very closely (Table 13.1).

The typical freshwater wetlands are vleis, which form in the catchment areas of highveld streams (spruits), where a sufficiently shallow gradient permits the soils to remain wet without being eroded by flowing water. Many of these vleis on the highveld are peat forming, especially where the dominant species is the reed *Phragmites australis*. Rietvlei in Gauteng is a prime example of a wetland with peat deposits sufficiently large to be suitable for mining. The perimeter around stagnant water bodies (lakes, banks of dams) as well as the 'Floodplain Vleis' of Noble & Hemens (1978; see also Rogers 1995) is here classified as part of Freshwater Wetlands as well. Many pans, especially on the precipitation-rich eastern and northeastern highveld are also considered freshwater wetland habitats. A very significant pan field is that of the Lake Chrissie region in Mpumalanga where over 250 pans occur—remnants of a fossil riverine system. The surrounding landscape is also very uniformly flat with an underlying layer of marine-deposited sandstone that forms the bed of many of the pans. These freshwater pans can be classified as Open Pans, Reed Pans, and Grass Pans (according to Rogers 1997; see also Geldenhuys 1982 for the definitions of these concepts), depending on vegetation cover and its composition. The narrow alluvia of highveld streams are also tentatively classified as part of the Freshwater Wetland category due to notable floristic similarity to the vlei vegetation.

The high-altitude wetlands of the Lesotho Highlands (with a small portion belonging to South Africa) enjoy particular status within southern African wetlands. They have been called 'bogs' (e.g. Van Zinderen Bakker 1955, Jacot Guillarmod 1962, Van Zinderen Bakker & Werger 1974), 'mires' (Backéus 1988) or 'flushes' and 'cushion bogs' (Thompson & Hamilton 1983), and they are characterised by the formation of peat—a phenomenon typical of precipitation-rich and cold climates (Gore 1983). These wetlands develop into depressions, and on slightly inclined slopes they are fed by rain water as well as lateral flow of water released from the peat layer down-slope. Hence, according to the hydrological classification (see for instance Walter 1968) they should be considered to be ombro-soligenous mires (influenced by rain water as well as water seeping through the soil). The water is eutrophic since the underlying basalt is rich in calcium, potassium and phosphorus and has a pH of about 8. The mires develop, in an oligotrophic direction (Van Zinderen Bakker & Werger 1974), under extreme precipitation conditions

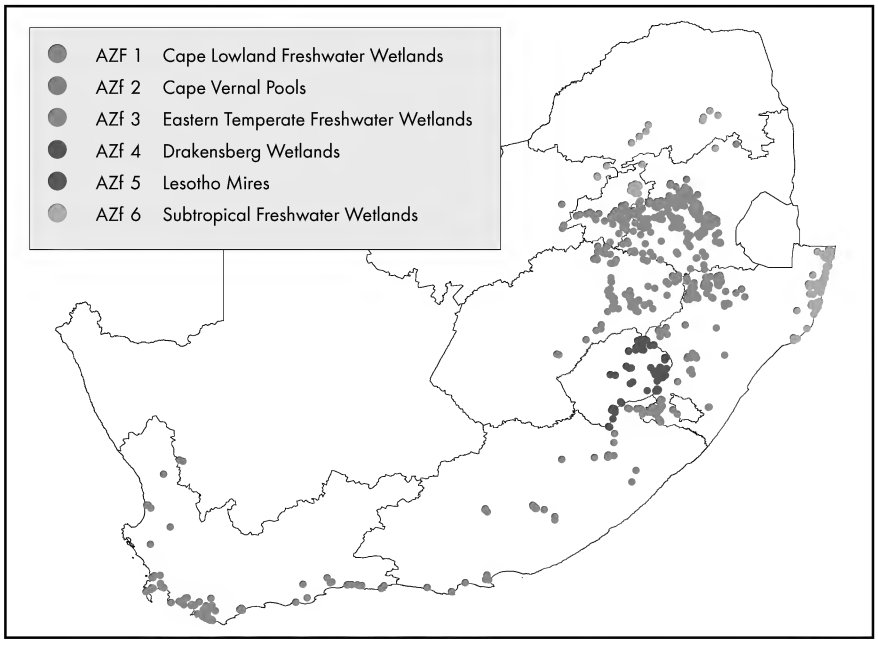

Figure 13.3 Position of patches of vegetation units featuring freshwater wetlands (AZf group) in South Africa, Lesotho and Swaziland.

leading to flushing of bases from the mineral-rich peat. Moist or so-called head-valley 'sponges' should not be included in the mire category since they do not show a marked rise in the peat layer. Formation of thufurs (small hummocks) and tarns (small water pools) are typical geomorphological and hydrological features of the Lesotho mires. The origin of the thufurs is still not fully understood, but uneven freezing/snowing patterns might be an obvious cause (see Van Zinderen Bakker & Werger 1974 for a review of the problem and Thompson & Hamilton 1983 for some comparative ideas). The high-altitude bogs and mires of southern Africa have a long evolutionary history and as evolutionary laboratories and museums, they house a high number of relicts of the past afromontane flora migrations and they also became a cradle of neo-endemism.

Peat layers are also formed in wetlands on the highest summit plateaus of the mountains in the southwestern Cape (Kruger 1979, Sieben et al. 2004). These are rain-fed and acidic and in the Cape they also receive a considerable amount of fog precipitation, also with some in summer (Marloth 1907). In summer these small peatlands experience seasonal drought (or at least considerable decrease in water content). Formation of typical raised bogs (purely ombrogenous mires) has not yet been observed.

All of the different freshwater wetland types as listed above can contain permanent water bodies qualifying as natural lakes (Allanson 1979, 1981, Hart 1995; Figure 13.4). The shallow fringes of these lakes support a variety of so-called macrophytic aquatic vegetation composed of various life forms adapted to life on the lake bottom, free-floating within a water column or floating on the surface of the water. These habitats are considered (also in accordance with the definition of a wetland of the Ramsar Convention) as wetlands, although we have not always mapped them.

The freshwater wetlands found outside the centres of regional endemism (Van Wyk & Smith 2001), and especially at low altitudes, show certain uniformity in terms of dominants and house a number of species of subcosmopolitan distribution. In regions known for their high endemism (Capensis, Drakensberg), their contribution to the scores of endemism is considerable (e.g. Drakensberg Wetlands, Cape Vernal Pools, Fynbos Riparian Vegetation and unmapped freshwater wetlands in the mountainous regions of the Fynbos Biome).

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Figure 13.4 Island Lake (Onder-Langvlei) near Wilderness on the Garden Route (Western Cape)—an example of a coastal freshwater lake separated from the sea by a high cordon of dunes.

3.2 Alluvial Vegetation

Southern Africa is a dry land, and it has been so since about the mid-Tertiary. Still, water has long been a major landscape-shaping factor. Tributaries of major perennial river systems, of which the Orange, Thukela and Limpopo are the most important water courses draining South Africa, Lesotho and Swaziland. There are many smaller ones dissecting the sloping face of the subescarpment regions of Namaqualand (e.g. Buffels), the southwestern and southern Cape (e.g. Berg, Breede, Gouritz) and the broad coastal slopes of the Eastern Cape (e.g. Gamtoos, Great Fish, Kei) and KwaZulu-Natal (e.g. Phongolo).

The systems of permanent and intermittent rivers of southern Africa, as we know them today, represent a snapshot in history of the evolution of our landscapes. Continental uplift and climate change events (and associated changing precipitation and through-flow patterns) have always driven the dynamics of formation, alteration and obliteration of riverine systems. The development of the Orange River basin (Wellington 1958, Dingle & Hendey 1984, De Wit 1999, Goudie 2005) has demonstrated beyond doubt that, since dryness became a dominant feature of the climate of our planet, the changes in the major riverine systems draining arid and semi-arid regions of southern Africa have been extensive.

All the extant perennial as well as intermittent rivers are accompanied by systems of alluvial terraces suited to support a special category of wetlands characterised by flooding and associated disturbance. Alluvium is usually defined as a place where sediments carried by a river are deposited. Typically, alluvia are flat terraces built of assorted sedimentary material, and regularly accompany the middle (partly) and lower (prevalently) reaches of slow-flowing rivers. Because the volume of water carried by rivers might change seasonally, the build-up of the alluvia follows these cyclic changes. The alluvia undergo frequent rebuilding by erosion of old or adding of new material, depending on the mobility of the river. As a river changes its direction or might cut deeper into the surrounding landscape, new systems of alluvial terraces are built, older ones are eroded away or abandoned in places where the influence of flooding has ceased. In general, typical alluvia are habitat complexes where sedimentation (hence habitat-creating) processes prevail over erosion (destructive) processes. The riverbanks of rapidly flowing, montane rivers, sometimes with rapids, along the upper river reaches with steep gradients can also develop alluvia. This happens especially in places where the valley carrying the river becomes broader or where gradients become less pronounced. There are several differences between these alluvia and those along the middle and lower reaches of a river. The mountain river alluvia are usually built of coarse sedimentary material including large boulders and gravel, they have a low nutrient status and they are exceedingly prone to extensive damage (and obliteration) by unpredictable catastrophic floods.

Alluvia support habitat complexes emerging as a result of the interplay of several ecological factors such as temporary and spatial sedimentation-to-erosion rates, water sediment load, water chemistry and nutrient content, frequency and

duration of flooding, soil texture and soil nutrient status, just to mention the most important ones. It has been shown (Van Coller 1993, Van Coller et al. 1997, 2000) that vegetation populating the alluvia is primarily structured by environmental gradients reflecting the habitat differences in the vertical (above), lateral (away from) and longitudinal (along) dimensions of the river channel. The elevation above the macrochannel explains the main variation in vegetation pattern, with processes of flooding frequency and water availability as major determinants of the vegetation cover on the alluvia (Van Coller et al. 2000). The latter authors further demonstrate that patchiness factors (such as presence of well-developed alluvial bars and quality of bedrock) also play an important role as vegetation-structuring processes.

The diversity of the alluvial habitats is considerable, which is reflected in diversified pertinent geomorphological and hydrological terminology. Ecologists have also coined several sets of terms describing alluvial habitats especially in relation to occurrence (and frequency) of flooding. Kopecký's (1969) typology of riverbank habitats is based on three criteria, namely (1) the vertical division of the riverbanks into riparian and subriparian zones, (2) range of the water level fluctuation, and (3) intensity of wave action or speed of flow. The amplitude of the fluctuation in water level defines either a stenosauletic type of riverbank (when the difference between maximum and minimum levels does not exceed 0.6 m) or a eurysauletic type (where water level fluctuates more than 1 m). Four 'ecotopes' (= habitats) can be distinguished within the stenosauletic type of riverbanks, depending on the duration of floods: the submerse ecotope is permanently flooded, the demerse ecotope is exposed only briefly during dry periods, the semi-emerse ecotope is usually dry as a rule, but flooded during shallow flood periods, and finally the emerse ecotope is the zone inundated only during high floods. An unpublished system by Boucher & Tlale (1999a; see also Sieben 2003) is in principle very similar to the one described above and involves three basic zones, namely Aquatic, Wet Bank (with Lower and Upper Zones) and Dry Bank (with Lower Dynamic, Shrub/Tree, and Back Dynamic zones).

Frequently flooded lower banks are usually populated by transient herblands made up of short-lived, nutrient-demanding flora. Reeds occupy beds forming on banks of very slow-flowing rivers or are found in still backwaters. Patches of flooded grasslands are usually found on both low and middle terraces, while riparian thickets usually occur on high terraces experiencing only occasional disturbance events resulting from floods. Permanent (or semipermanent) alluvial lakes or backwaters can form within extensive alluvial complexes. They may diminish in size and expose broad bands of clayey banks in regions characterised by seasonal rainfall. The actual water bodies in this habitat complex, including the backwater (pan) lakes, oxbows as well as slow-flowing river channels, may support macrophytic vegetation (*sensu* Hejný 1960)—true aquatic vegetation built of plants floating on the water surface or dwelling within the water column. These patterns hold for most of the perennial river systems and occur in modified form also on alluvial complexes accompanying intermittent rivers. The narrow mountain alluvia can support herblands, restiolands and sedgelands consisting of disturbance-resistant clonal plants. They also support thickets such as those constituted by endemic shrubs in Capensis and *Leucosidea sericea* in the Drakensberg.

The alluvial vegetation shows many common floristic and ecological features across the biomes of southern Africa (Figure 13.5), resulting from selection of plant functional types that respond well to high water supply, occasional (and sometimes heavy) disturbance and extraordinarily high nutrient status (especially in the case of lower alluvia). Disturbance, both natural and man-induced, in these habitats creates a set of conditions allow-

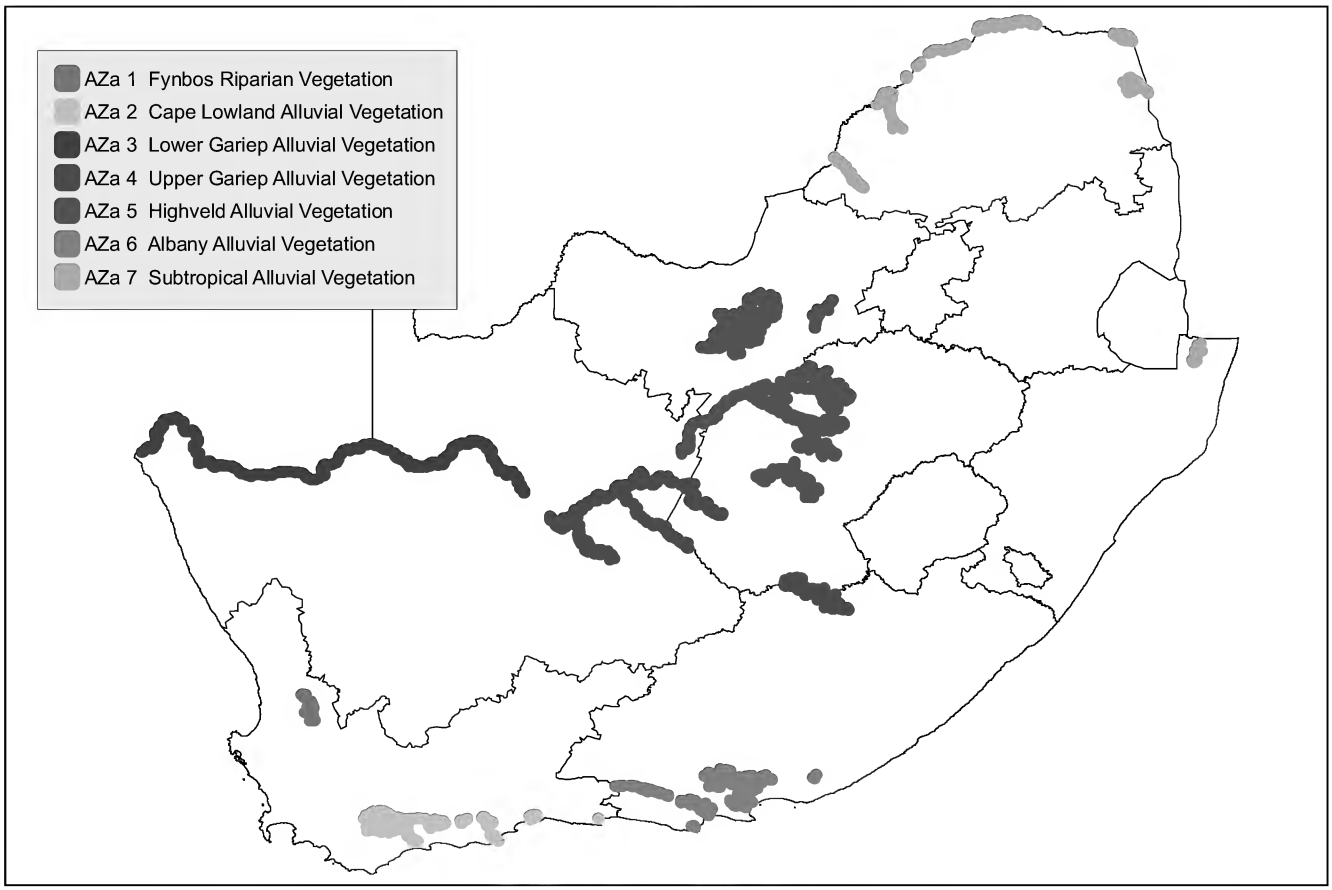

Figure 13.5 Position of patches of vegetation units featuring alluvial (and riparian) wetlands (AZa group) in South Africa.

ing and fostering the rapid spread of highly responsive native, ruderal flora. Alluvia also serve as important corridors for linear invasions by alien flora (e.g. Duvenhage 1993, Pyšek & Prach 1994; see also Macdonald et al. 1986).

3.3 Inland Saline Vegetation

The salt-laden habitats found inland, hence outside the immediate influence of the sea, are diverse in character and origin. Still they do share several basic ecological features, such as a high concentration of salt soil and water. The salinity originates either from a salt-bearing substrate or from mineral-rich groundwater aquifers, typically those located close to the soil surface, or from other forms of water that seep to the surface and deposit salt after evaporation. Inland saline habitats are found in regions that experience a prolonged dry period.

The most prominent inland saline habitats are those in and around salt pans (Allan et al. 1995), also called 'closed drainage salt pans' (Rogers 1995) and 'vloere' or 'kolk' by the local population in Bushmanland (the latter also called 'Karoo salt flats' by Rogers 1995). The term 'endorheic' is often used for these pans and refers to the closed nature (no outlet) of the drainage system of the pans. The size of the salt pans can range from very small to very large (such as Grootvloer in Bushmanland). Typically, they are filled with fine clayey sediments with a high salt content (pH of soil regularly exceeding values of 8). Most of them are dry for most of the year, while only some carry water (subject to large water-column fluctuations) all year round. The central, flat part of many pans is usually devoid of vegetation, and typical vegetation zonation patterns may form at the edges of the pan floor and on the banks of the pan.

Marshall & Harmse's (1992) review of the knowledge on the origin and formation of pans revealed the complexity of this interesting natural phenomenon. The authors concluded that there are three basic integrated mechanisms of pan initiation involving (a) suitable substratum (easily weathering rocks such as those of Karoo Supergroup sediments), (b) disrupted drainage (induced either by tectonic or climate-change processes), and (c) geological structure (including the presence of dolerite sills, fracture intersections and volcanism). Deflation and the concentration of animals around pans (to drink and wallow) may play an enhancing role in the formation of the pans. The concentrated occurrence of inland salt pans coincides with ancient (usually Tertiary) river systems, for example those of the northern and western Free State (Grobler et al. 1988) or the Orange (Gariep) River (Wellington 1958). Because of the conserving properties of high salt concentrations, the pan sediments preserve pollen and other remains of organisms, which are used as an important source of palaeoecological information (e.g. Scott & Brink 1992, Partridge & Scott 2000).

The most extensive salt pan systems in South Africa are found in Bushmanland, the northeastern Free State and in the adjacent regions of the North-West Province. The name of the region is derived from the salt pans of the Kalahari (Figure 13.6).

The salt pans along the Atlantic seaboard of the West Coast are of marine origin. These pans used to be coastal lagoons and as they became fully severed from the sea, they turned into salt pans (Rocher Pan near Velddrif, salt pans near Darling and Cape Town). The pans of Namaqualand as well as those of the Agulhas Plain and of the plains bordering the Indian Ocean further east (near Albertinia in the Western Cape, Uitenhage and Despatch in the Eastern Cape) are remnants of Pleistocene marine transgressions.

In the Overberg region (typically made up of salt-laden Bokkeveld Shales), and to a small extent also in other regions

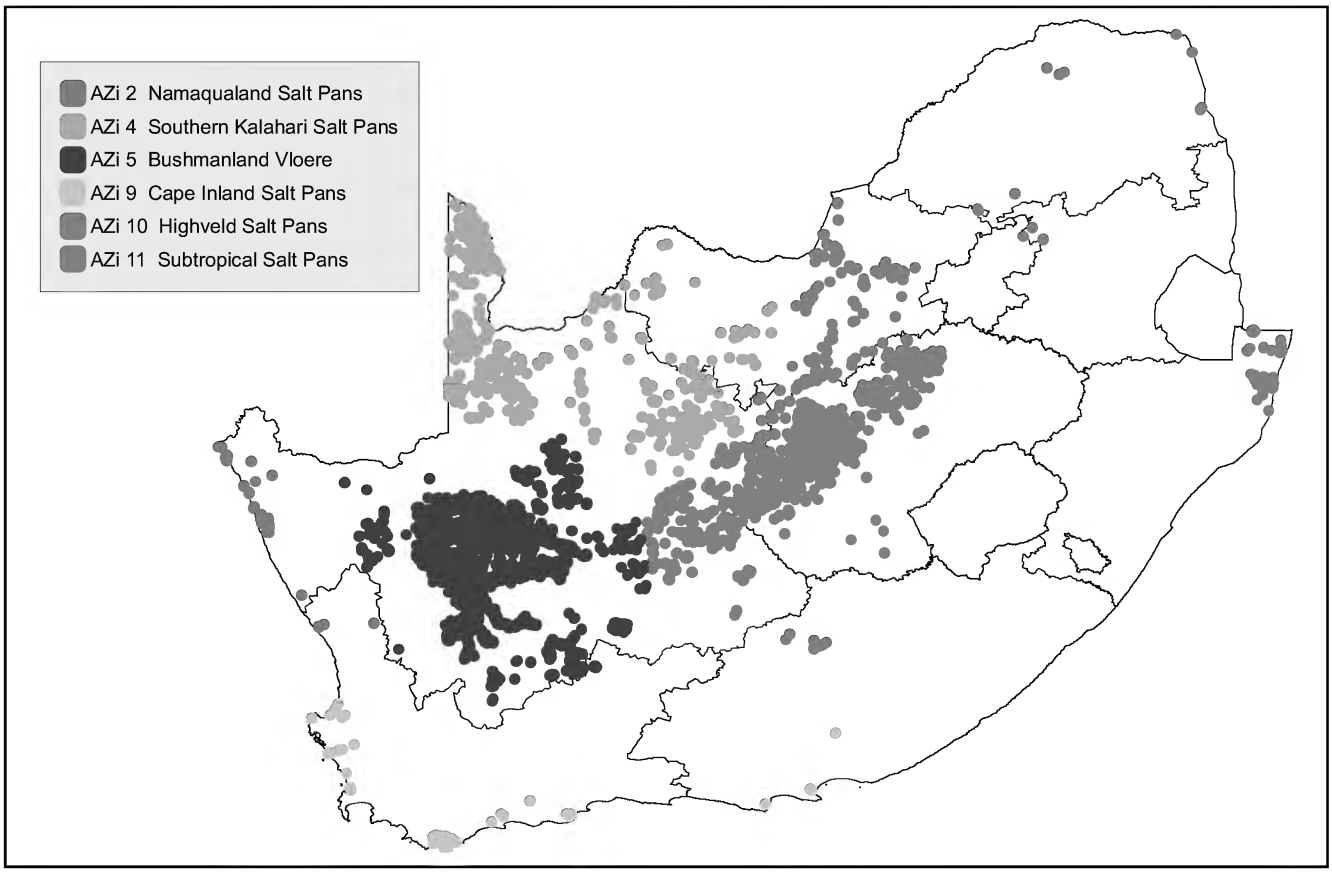

Figure 13.6 Position of patches of inland salt-pan vegetation units (part of AZi group) in South Africa.

consisting of shales of different origin (around Worcester and Malmesbury), inland saline vegetation is limited to erosion scars and to narrow alluvia collecting salty, clayey, shale-derived sediments. Quite extensive salt alluvia and flats are especially found in the vicinity of Bredasdorp, Napier and Swellendam.

Salt pans in the subtropical regions of South Africa and Swaziland are another, special wetland category. They are well known to both South Africans and tourists for excellent game viewing in the parks and nature reserves of the Lowveld and the Central Bushveld, especially in the dry season (summer), when some of them still carry some water or turn into muddy pools (Figure 13.7). These natural pans are usually either remnants of dysfunctional drainage systems or are formed in drainage lines of intermittent rivers. They are seldom formed in deflated depressions, sealed with clayey sediments and perpetuated (and extended) by animals visiting the water pools emerging from them from time to time. Only one of these pans is known to be of impact (meteorite) origin—Soutpan in the Tswaing Crater, north of Pretoria. The most extensive subtropical pans are those of the Ndumo Game Reserve (Nyamiti and Banzi) and other pans of the same riverine (Phongolo) system in Maputaland, and the pans in the Lowveld (Kruger National Park). The subtropical pans in South Africa provide habitats for tropical hygrophytes and hydrophytes at the southern limits of their distribution (Cook 2004) and are of enormous conservation importance for maintenance of populations of megaherbivores (Figure 13.8) and water birds.

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Figure 13.8 Lowveld pans are important habitat of large herbivores: young hippo (*Hippopotamus amphibius*) in an artificial pan filled with alien *Pistia stratiotes* (Araceae) near Lower Sabie Rest Camp in the eastern Kruger National Park.

Azonal vegetation is also found on the bottom and on slopes of hardpan (mainly calcrete, sometimes also ferricrete and silcrete) edges of dry riverbeds criss-crossing the driest parts of South Africa (Figure 13.9). The drainage channels of intermittent rivers, called 'waadi' in Arabic-speaking countries or 'riverwash' in America, are a typical feature of semidesert and desert landscapes of southern Africa. In the Kalahari they are called 'mekgacha' (plural); in Namibia, Walter (1985) adopted the Afrikaans term 'riviere' (plural) for them.

The mekgacha and riviere are dry most of the year. In fact, they may stay dry for many consecutive years. They very seldom are in flood and then only for a short time, immediately after heavy (often unexpected) rains and are usually not able to carry the flood surges far. Water typically recedes very quickly (sometimes within hours) and disappears into the sandy riverbeds, where it can persist in the soil column (as capillary water) or form small aquifers. Erosion and sedimentation cycles redistribute not only water-borne soil particles, larger rock debris or dead plant material, but also seeds and entire mats of creeping grasses. This natural plant propagation material provides the foundation for a new vegetation cover on the dried bottom of the intermittent rivers after the waters have receded and soil particles have settled.

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Figure 13.7 Nyamiti Pan in Ndumo Game Reserve (Maputaland, KwaZulu-Natal). *Cynodon dactylon* sward covers the proximal pan bank, while *Acacia xanthophloea* (fever tree) dominates the opposite upper bank of the pan.

The drainage lines of the intermittent rivers are often associated with outcrops of hardpan (mainly calcrete), which supplies (through erosion and in times of flood surges or through seeps in the calcrete riverbanks) high levels of calcium in the soil. High evaporation pressure leads to salt accumulation on the surface (also on the dry bottom of intermittent rivers). It is therefore not surprising that the vegetation of dry river bottoms is of halophytic character.

The drainage systems of (semi)desert intermittent rivers are probably very old as the events leading to dramatic change of the course are rare.

The classification of vegetation units related to salt-laden habitats of intermittent rivers follows the same principles as for salt pans—the position of the respective vegetation unit in relation to the surrounding biome (Figure 13.10).

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Figure 13.9 Valley-bound view of the subescarpment plains of the Knersvlakte below the Vanrhyns Pass (on the border between Northern and Western Cape) with tributaries of drainage lines carrying intermittent water courses fringed by *Acacia karroo* thickets.

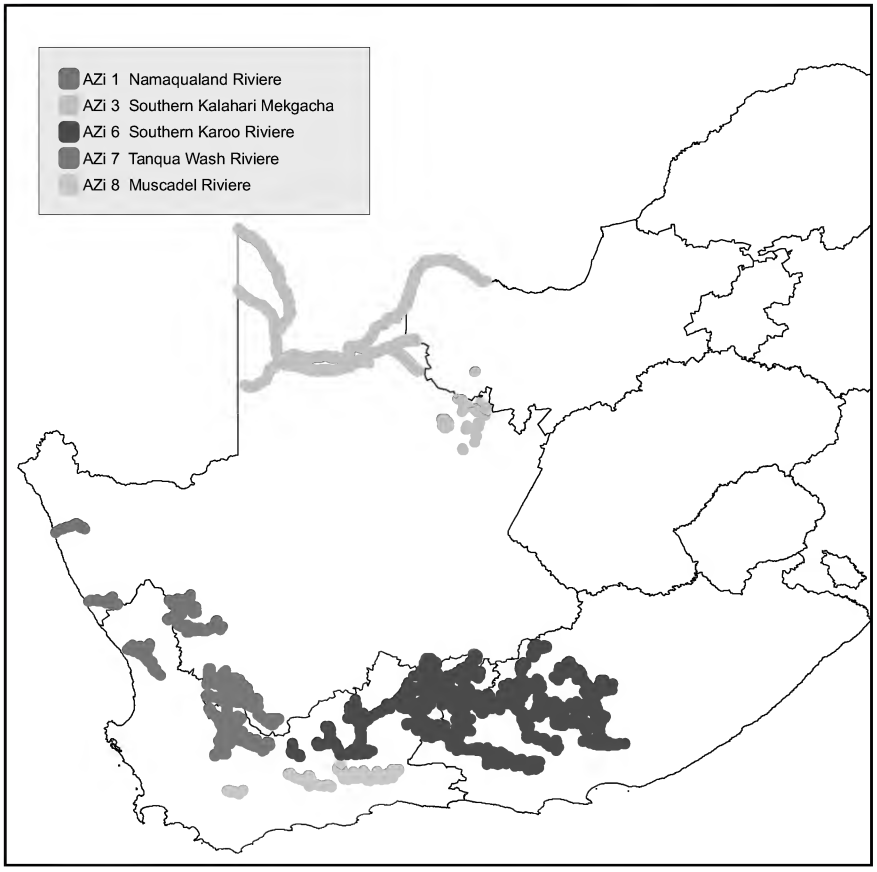

Figure 13.10 Position of patches of vegetation units (part of AZi group) featuring vegetation of intermittent rivers and associated habitats in South Africa.

4. Caveats: Neglected Azonal Vegetation

Much of the Freshwater Wetlands escaped mapping at this stage due to their small extent and lack of data. We admit that the major caveats are in the coverage of Freshwater Wetlands of the Cape Fold Mountains, Highveld, Drakensberg (and adjacent parts of the Great Escarpment) and KwaZulu-Natal and Eastern Cape coastal forelands. We still lack proper data on the extent of alluvia of the Cape forelands, Highveld, Central Bushveld, Lowveld and KwaZulu-Natal and the Eastern Cape coastal belt (and deep inland coastal forelands). The mapping of the extent of units such as AZf 4 Drakensberg Wetlands, AZa 1 Fynbos Riparian Vegetation and AZa 2 Cape Lowland Alluvial Vegetation is in its infancy.

The recognition of Freshwater Wetlands embedded within the Fynbos Biome (especially fynbos shrubland units—see chapter on Fynbos in this book) is the major challenge for future vegetation mapping. These wetlands encompass a plethora of habitats classified by Sieben et al. (2004) into four major habitat complexes, namely slope seepages, valley seepages, high-altitude fens (called 'acid fens' by Rogers 1997), and restio marshlands (Figure 13.11). Apart from several notable exceptions (such as restio marshlands near Rawsonville in the Breede River Valley and temporary wetlands of the Agulhas Plains), these habitats are small and mainly mappable only at scales below 1:50 000 (see Boucher 1978). Like its surrounding zonal vegetation, the Fynbos Freshwater Wetlands show high levels of endemism and regional distinctness resulting from high beta diversity across the coenoclines of freshwater fynbos communities. Classification of such a highly fragmented archipelago of habitats and associated vegetation showing high levels of distinctive species composition, remains an exciting challenge.

Despite the high diversity of azonal vegetation types featured in this chapter, the list is far from complete. We admit to have disregarded a number of very specific vegetation types—potential subjects for more detailed future mapping exercises. We believe that all these small-scale vegetation units can be mapped at scales spanning 1:5 000 to 1:50 000. Among those, we wish to mention:

(a) Vegetation of inland cliff faces and crevices, rock ledges and sheets

Inland cliffs create a plethora of microhabitats supporting specific vegetation reflecting geology, soil-trapping (and erosion) processes, duration and intensity of insulation (a function of aspects and shading by surrounding landscape features), presence of trickling or seeping water, disturbance by animals and several other ecological factors. They are found on steep slopes along the Cape Fold Mountains and Great Escarpment as well as deep gorges (Figure 13.12) cutting the table landscapes of southern Africa. Poor accessibility (hence protection from grazing pressure), low levels of competition and often relative habitat stability over millennia (and possibly even longer) are prerequisites for the presence of relict and endemic

flora. Brief accounts of this kind of community are scattered in reports of the Nama-Karoo Biome (Werger & Coetzee 1977, pp. 19, 20) and the Grassland Biome (e.g. Hilliard & Burtt 1987, pp. 54–56, Siebert et al. 2003). Unlike in the northern hemisphere, in South Africa research on the flora and vegetation of rocky habitats is in its infancy (Van Jaarsveld & Van Wyk 2000, 2003). Given the basic geometry of plain-surface mapping, the depiction of the vegetation of near vertical cliffs on such maps might be a challenge, even at a scale of 1:5 000.

(b) Vegetation of rock overhangs and cave openings

Cave openings and rock overhangs are a very special habitat characterised by steep gradients, low moisture (due to shelter effect) and often a high nutrient-status of the soil due to frequent visits by both humans and animals seeking shelter. Because of the slow rates of rock weathering, these shelters remain for tens to hundreds of thousands of years, hence long enough to allow evolution of specific flora. Herbs such as *Crassula densa* (Werger & Coetzee 1977, p. 20), *C. umbraticola*, *Cynoglossum spelaeum*, *Juncus mollifolius* (endemic to the Drakensberg), *Lappula squarrosa*, *Malva verticillata*, *Nemesia rupicola*, *Parietaria micrantha* and *Troglophyton capillaceum* (all cited by Hilliard & Burtt 1987, pp. 60, 61) and shade-tolerant ferns *(Adiantum capillus-veneris*, *A. poiretii*, *Asplenium trichomanes*, *Blechnum australe*, *Cheilanthes hirta*, *Cystopteris fragilis*, *Mohria caffrorum*, *Woodsia montevidensis* var. *burgessiana* etc.) have been reported from the rock overhangs.

(c) Vegetation of ephemeral freshwater wetlands of (semi-)arid regions

Ephemeral wetlands in semidesert and desert regions usually form in close proximity of (temporary) springs or on banks of temporary streams. Some of the plants are ephemeral annual herbs, while others may survive the dry period by means of bulbs and corms in the soil until their habitat is soaked the next time. For instance, extensive granite-derived coarse-sand seeps emerge in high-rainfall years in central Namaqualand, showing a rich display of bulbous flora well adapted to this habitat. To an extent these habitats simulate synecological conditions of AZf 2 Cape Vernal Pools. Short-lived wetland species such as *Cotula coronopifolia* and *C. nigellifolia*, and bulbous plants such as *Androcymbium dregeanum*, *Bulbine latifolia* var. *latifolia* (Figure 13.13), *Oxalis namaquana* and *Romulea pearsonii* are floral gems typical of these ephemeral wetlands.

(d) Vegetation of temporary rock pools

Temporary rock pools (Figure 13.14 and 13.15) are a quite common small-scale habitat, supporting fascinating assemblages of plants and animals. They come alive during the rainy season and are especially encountered in depressions on the surface of rock sheets and outcrops of granite and gneiss (Cape granite plutons, Namaqualand, Richtersveld, Augrabies Falls; e.g. Werger & Coetzee 1977, p. 21) as well as sandstone and quartzite (Cape Fold Mountains, the Karoo Escarpment and Drakensberg; e.g. Hilliard & Burtt 1987, pp. 39, 40). Typical species sharing the short-lived water pools with fairy shrimps are *Aponogeton desertorum, A. stuhlmannii, Crassula aphylla*, *C. elatinoides* (endemic to the top of Table Mountain), *C. inanis*, *C. natans*, *C. vaillantii*, very rare *Isoetes stellenbossiensis*, *I. stephanseniae* (both in the Cape), *I. toximontana* (endemic to Gifberg), *I. transvaalensis* and *I. welwitschii* (both occurring in the eastern part of the country), *Limosella africana*, *L. grandiflora*, *L. inflata, Lindernia conferta*, *L. pulchella* and *L. wilmsii* etc. The temporary rock pools found in winter-rainfall regions are of particular interest due to high levels of endemism.

The major reason why these specific vegetation complexes (indeed deserving status as mapping entities) are not featured on our map is their extremely small size and patchy occurrence. We believe that they will receive proper attention in local classifications and microscale mapping studies as in the past (Boucher 1972, 1978).

5. Conservation Challenges: Status, Threats and Action

Conservation and restoration of wetlands (including riverine vegetation and rivers) in southern Africa have been the subject of a number of reports, proceedings, chapters and books (e.g. Noble & Hemens 1978, Denny 1985, O'Keeffe 1986, Begg 1990, Dallas & Day 1993, Davies et al. 1993, Cowan 1995c, Thieme et al. 2005; see also reports of the Water Research Commission, website: http://www.wrc.org.za). In this work we want to highlight only briefly sev eral issues directly pertinent to conservation and the wise use of wetland vegetation.

5.1 Value of Wetlands

Water is one of the essential preconditions of life. It is a renewable resource, but the 'renewability' has its limits and has to be addressed in countries experiencing water shortages. South Africa is a dry land (at least most of the area for most of the year) and therefore the water availability, its spatial and temporal distribution and, last but not least, its quality, are of national strategic importance. Vegetation occupying wet (albeit often only temporarily) areas carries important information about parameters such as water quantity, position and status of the groundwater table and aquifers, chemical composition of water and sources of pollution.

Wetlands are home to many rare plant species, including ecological specialists and relicts of past migration patterns. To an extent wetlands are both evolutionary museums and laboratories. In the light of their high biological value as a habitat for resident and migratory waterfowl, the international conservation community has recognised the role of some wetlands as crucial. The Convention for Conservation of Wetlands (also known as the Ramsar Convention; see Cowan 1995a, b, 1999) declared in 1971, has so far recognised 16 wetland areas (most of them freshwater ones) in South Africa as members of the Ramsar wetland network. Tourism is a major industry in South Africa and depends largely on wildlife conservation as its major attraction. Therefore protection of spectacular water-dwelling wildlife such as crocodile, hippo, otter and water birds is not only a matter of conservation in its own right or the evolutionary responsibility of mankind, but has become an important economic factor.

5.2 Threats to Wetlands

The principle threats to wetlands include the conversion of a wetland from one form to another (changing the status of the wetland) and reduction in size, often resulting in the total demise of the wetland habitat.

Conversion usually involves the erection of structures within the wetland, typically dams. Impounding causes changes in the functioning of the wetland by reducing the flow of water downstream while increasing the inundation period and/or depth of inundation. These interventions initiate changes in the structure of biota populating the wetland. Excessive water pollution results in shifts from oligotrophic (usually very diverse habitats

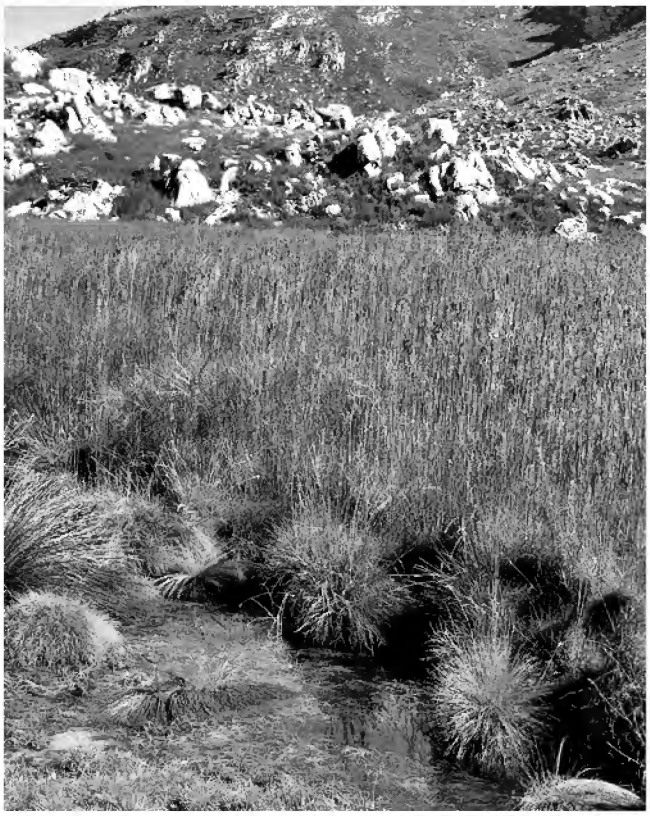

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Figure 13.11 Restio marshland (mire) below Landdroskop in the Hottentots Holland Mountains. The dominant plants are *Ursinia caledonica*, various species of *Elegia* and *Anthochortus crinalis*.

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Figure 13.12 Complex of steep cliffs, rock ledges, deep cracks and fissures housing fragments of fynbos vegetation and specific chasmophytic (cremnophilous) vegetation in the Storms River gorge (west of Humansdorp, Eastern Cape).

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Figure 13.13 *Bulbinella latifolia* subsp. *latifolia* (Asphodelaceae) in a temporary vlei overgrown by alien *Populus*, south of Grootvlei near Nieuwoudtville (Northern Cape).

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Figure 13.14 Temporary mini-wetland—a rock pool in Nardouw sandstone on the Bokkeveld Plateau (near Nieuwoudtville, Northern Cape) with *Crassula aquatica*.

of high conservation value) to eutrophic wetlands, often dominated by single ubiquitous species choked by algal blooms.

Drainage of a wetland involves both diversion of water away from the wetland, as well as the extraction of water from the wetland itself via drains. This results in changes in the species composition from wetland species to a habitat dominated by purely terrestrial species, as well as changes in the soils from typically anaerobic to aerobic. In urban areas, housing developments are a specific problem. Occasionally this is due to ignorance, but often a developer will deliberately set out to destroy a wetland should it be present on a development site. Urban wetlands, especially, are subject to increased water runoff from hard surfaces. Although the total volume may be similar, the water flows faster into and through the wetland, resulting in increased erosion. A common source of headcuts, where erosion gullies form in the wetland, is the construction of culverts permitting roads to cross wetlands. The bottom of these culverts are often much lower than the surface of the wetland, resulting in erosion.

The main pollution threats to wetlands are petrochemical spills, unprocessed or semiprocessed sewage, fertiliser and pesticide runoff, and dumping, both of garbage and rubble. Petrochemical spills are toxic to most organisms, including the vegetation, of a wetland. These are often due to indiscriminate disposal of lubrication oils into storm-water drains, as well as from runoff from roads. The dumping of sewage is usually due to blockages and bursts in sewage pipes discharging organic wastes into wetlands. This results in the increase in the *Escherichia coli* count as well as an increase in organic matter, phosphates and nitrates in the system. Sewage processing plants usually discharge treated water into wetland systems. Although the dissolved organic solids may have been removed from this water, it is usually high in phosphates and nitrates. Surplus of fertilisers and especially pesticides used in the agricultural industry usually end up in wetlands via surface runoff or infiltration into the water table. Phosphates and nitrates form the bulk of agricultural fertilisers. Wetlands are often perceived as wasted space, and as such are used as unofficial dumpsites for household and garden refuse as well as rubble from construction sites.

Many of the species declared as alien invasive weeds are wetland species. These species have varying effects on wetlands, from the displacement of indigenous species to unduly high extraction of water from wetlands and rivers. For instance, Le Maitre et al. (2000) estimated that the total incremental water use of invading alien plants attained 3 300 million m^3 of water per year—an equivalent to about 75% of the virgin MAR of the Vaal River system. Alien infestation is often exacerbated by nitrate and phosphate pollution. Some species such as *Eichhornia crassipes* increase the evaporation from water bodies and alter the nutrient and oxygen levels of the water. Much attention has been devoted to controlling this species (for extensive literature on *Eichhornia crassipes* see Gopal 1987 for a global review, and Thompson et al. 1985 and O'Keeffe 1986 for references relevant to Africa). Still more research and management effort (despite the very successful Working for Water Programme launched in 1996) is needed to understand and to bring these invaders under control.

Some fast developing regions of South Africa sometimes experience water shortages during dry periods, leading to the implementation of water-saving measures. Because of the lack of surface water, new sources are being investigated, natural underground reservoirs in particular. Water extraction from aquifers such as those in sandstones of the Cape Fold Mountains is being considered. However, care must be exercised as uncontrolled and scientifically ill-funded extractions can easily lead to the demise of fynbos seeps, which support hundreds of local endemics.

5.3 *Sustainable Use and Restoration of Wetlands*

Wetlands have long been sources of vital resources for human populations, water being the most important commodity. Apart from supplying water, wetlands have other major roles in a healthy functioning landscape, for instance in matter and nutrient cycling, source of food for grazing animals, protein for humans (wild fowl, fish) or material for building shelters. A wise farmer knows that his springs and vleis can be used in a sustainable way only when the carrying capacity is not superseded. Reed beds can recover easily if harvesting is done wisely according to sustainable scenarios (e.g. McKean 2001, Van Rooyen et al. 2004).

Legal conservation of extant well-preserved wetlands is in place in many parts of South Africa, but more extensive measures are called for. First and foremost, development of extant wetlands must be halted. Uses of wetlands that might lead to conversion from one form such as a vlei, to another, such as an impoundment, should be abandoned. It is not too late for many altered wetlands and rehabilitation is possible.

6. Research Challenges

Obvious economic interests made water and water biota the focus of a number of research groups and organisations such as the Water Research Commission (established in terms of the Water Research Act—Act 34 of 1971), South African Institute for Aquatic Biodiversity at the Rhodes University in Grahamstown (a national research facility of National Research Foundation), the Freshwater Research Unit at the Department of Zoology, University of Cape Town, the Centre for Environmental Management of the University of KwaZulu-Natal in Durban, the Centre for Water in the Environment at the University of the Witwatersrand and hydrogeology and hydrochemistry research at the Department of Earth Sciences of the University of the Western Cape. However, our understanding of variability and biodiversity of wetlands (and saline habitats), and the functioning of wetlands in regional and continental nutrient-energy cycling context is calling for more research.

The long list of references at the end of this chapter (see also Thompson et al. 1985 and Rogers 1997) may suggest that vegetation of inland wetlands as well as vegetation of salt-laden habitats has received much attention in South Africa, Lesotho and Swaziland. However, most of the published academic research on wetlands in South Africa (and neighbouring countries) is fragmented by focusing on small areas or by giving the wetlands only marginal attention in studies devoted to zonal vegetation such as grassland and savanna. An integrated and comprehensive picture of the distribution and variability of the wetlands is still outstanding. Effective conservation (see above) of the wetlands and saline habitats is very much dependent on knowing the scale of variability (biodiversity) of these special and vulnerable habitats. We do have some management tools, such as regional classification systems, and now also floristic-biogeographical systems at hand (presented in this chapter), but a comprehensive habitat classification system for wetlands remains lacking (see also lament by Rogers 1997). Our classification is a large-scale one and intuitive, although based on meta-analysis of available information, including extensive and well-defined data sets. More rigorous data treatment is neces-

sary. Vegetation ecological research and conservation practice in the northern hemisphere has identified the floristically based approach as very effective in identifying patterns (classification of wetland plant communities, identification of indicators of environmental change). A classification system of habitats (including wetlands) adopted in the European Union Habitat Directive (see Rodwell et al. 2002 for analysis of relations of this document to existing habitat databases) has become a powerful tool for nature land managers and conservationists.

The relative simplicity of wetland habitat in terms of only a few dominating environmental gradients, relatively easily predictable pattern formation and low species diversity, but high plant-functional group diversity make wetlands an ideal model for testing theories of community assembly at a small scale.

7. Descriptions of Vegetation Units

Freshwater Wetlands

AZf 1 Cape Lowland Freshwater Wetlands

Including *Phragmites*, *Scirpus* or *Typha* Reed Beds (Boucher 1978). *Aponogeton–Sporobolus* Community & *Potamogeton–Aponogeton* Vlei Community (Campbell et al. 1980). Submerged Aquatic Communities, Emergent and Wetland Communities & *Tetragonia decumbens–Senecio halimifolius* Moist Dune Community (O'Callaghan 1990a).

Distribution Western Cape Province: Freshwater inland vleis, edges of water bodies, such as Verlorenvlei (West Coast), De Hoop Vlei, Cape Flats vleis, Papenkuils Wetland, some vleis of the Agulhas Plains and Wilderness Lake System (between George and Knysna). This azonal unit is embedded within various types of renosterveld (especially those on shale) and the alluvial fynbos of the Fynbos Biome. Altitude ranges from close to sea level to mainly 400 m.

Vegetation & Landscape Features Flats and landscape depressions with extensive tall reeds of *Phragmites australis* and *Typha capensis*, temporarily or permanently flooded restiolands, sedgelands and rush-beds as well as macrophytic vegetation embedded in permanent water bodies.

Geology, Soil & Hydrology Substrate built of fine sandy, silty and clayey soils over young Quaternary sediments, largely derived from weathering Cape Supergroup shales and Cape granites as well as Table Mountain sandstones. They fill depressions and accompany broad alluvia of lowland rivers. The major source of water is either permanent (banks of permanent lakes) or temporary (hence either of riverine origin or result of high winter precipitation). In places (especially due to salt leaching from Malmesbury Group shales), these wetlands can acquire a brackish character.

Climate Seasonal winter rainfall (West Coast) to nonseasonal (South Coast) climate regime, but still characterised by general prevalence of winter rainfall. MAP ranges between 175 and 845 mm. Characterised by typical warm-temperate regime with MAT spanning 16.0–17.6°C. Incidence of frost is infrequent. See also climate diagram for AZf 1 Cape Lowland Freshwater Wetlands (Figure 13.2).

Important Taxa ([B]Brackish habitats): **Marshes** Low Shrub: *Senecio halimifolius*. Graminoids: *Paspalum vaginatum* (d), *Diplachne fusca*, *Juncus rigidus*[B], *Pennisetum macrourum*, *P. thunbergii*, *Polypogon monspeliensis*[B], *Stenotaphrum secundatum*[B]. Herbs: *Berula erecta* subsp. *thunbergii* (d), *Falkia repens* (d), *Chironia decumbens, Conyza pinnatifida, Epilobium hirsutum*, *Persicaria decipiens, Samolus valerandi*. Geophytic Herbs: *Triglochin bulbosa*[B] complex, *T. striata*[B]. Succulent Herb: *Sarcocornia natalensis* agg.[B] (d). **Reed & sedge beds** Megagraminoids: *Bolboschoenus maritimus*[B] (d), *Phragmites australis* (d), *Typha capensis* (d), *Cladium mariscus* subsp. *jamaicense*, *Cyperus thunbergii*. Graminoids: *Ficinia nodosa* (d), *Juncus kraussii* subsp. *kraussii*[B] (d), *Carex clavata, Cyperus denudatus*, *C. sphaerospermus*, *C. textilis*, *Pycreus nitidus*. Low Shrub: *Plecostachys serpyllifolia* (d). Geophytic Herb: *Zantedeschia aethiopica* (d). **Water bodies** Aquatic Herbs: *Myriophyllum spicatum* (d), *Nymphaea nouchali* var. *caerulea* (d), *Aponogeton junceus*, *Ceratophyllum demersum*, *Nymphoides indica* subsp. *occidentalis*, *N. thunbergiana*, *Potamogeton pectinatus*, *Ruppia cirrhosa*[B], *R. maritima*[B], *Zannichellia palustris*. Macroalgae: *Chara globularis*, *Lamprothamnium papulosum*[B], *Nitella dregeana*.

Endemic Taxa **Marshes** Low Shrubs: *Passerina paludosa*. **Water bodies** Aquatic Herbs: *Aponogeton angustifolius* (d), *A. distachyos* (d), *Cotula myriophylloides*.

Conservation Target 24%. Some 14% statutorily conserved in the Cape Peninsula and Agulhas National Parks as well as in the proposed Garden Route National Park, Rondevlei and Zandvlei Bird Sanctuaries as well as in Botrivier, De Hoop, Doringrivier, Salmonsdam, Verlorenvlei and Walker Bay Nature Reserves. De Hoop Vlei, Verlorenvlei and Wilderness Lakes (formerly within

L. Mucina

Figure 13.15 AZf 1 Cape Lowland Freshwater Wetlands: *Wachendorfia thyrsiflora* (Haemodoraceae) in a *Typha capensis* reed bed on the edge of a small dam in the Helderberg Nature Reserve (Somerset West, Western Cape).

the Wilderness National Park) enjoy Ramsar site status. More than 2% is also protected in private nature reserves such as Rietvlei, Oude Bosch, Groothagelkraal, Kleyn Kloof, Sandies Glen and Vergaderingskop. More than 15% has been transformed to cultivated land, plantations and urban areas. The vegetation of these wetlands is prone to invasion by alien shrubs (*Acacia saligna*, *A. longifolia*, *A. mearnsii*), herbs (*Apium inundatum*) and grasses such as *Pennisetum clandestinum* (kikuyu grass) and *Paspalum dilatatum*.

Remarks Unlike marshes and seeps dominated by endemic elements of the Capensis (preliminarily included within particular vegetation units of the Fynbos Biome), this vegetation has a (sub)cosmopolitan character indicated by the occurrence of a number of species with worldwide distribution in analogous habitats.

References Marloth (1908), Adamson (1929), Stephens (1929), Phillips (1931), Liversidge (1955), Martin (1960a, b), Middlemiss (1960), Taylor (1969), Andrag (1970), Van der Merwe (1976), Boucher & Jarman (1977), Van der Merwe (1977b), Linder (1978), Noble & Hemens (1978), Lamprecht (1979), Weisser (1979), Campbell et al. (1980), Howard-Williams (1980b), Howard-Williams & Liptrot (1980), Jacot Guillarmod (1982), Weisser & Howard-Williams (1982), Allanson & Whitfield (1983), Hall (1985), Boucher (1987, 1996b, 1999a, b, c), O'Callaghan (1990b), Weisser et al. (1992), Boucher & Rode (1995), Privett (1998), http://www.ngo.grida.no/soesa/nsoer/resource/wetland/sa_ramsar.htm.

AZf 2 Cape Vernal Pools

Distribution Western and Northern Cape Provinces: Cape Peninsula, Cape Flats and West Coast (especially between Hopefield and Piketberg) as far north as the surrounds of Vanrhynsdorp and Nieuwoudtville. This azonal unit is embedded within some shale renosterveld and sand fynbos units of the Fynbos Biome. Altitude ranging from 50–850 m.

Vegetation & Landscape Features The vegetation is distinctly zoned, with fringing species that occupy waterlogged soils surrounding the pools plus specialised aquatics that are rooted in the mud but often have floating stems or leaves. The zone of fringing species which grow in water up to 2 cm deep, comprises a band up to 2 m wide of various small annuals, typically species of *Crassula* (e.g. *C. vaillantii*, *C. natans*) and of *Cotula* (e.g. *C. coronopifolia*) along with several small geophytes, such as species of *Trachyandra*. The small aquatic *Limosella* with floating leaves is also found in this zone. Later in the season as the margins dry out, larger bulbs such as *Ornithogalum thyrsoides* predominate. The specialised aquatics grow in waters deeper than 2 cm although seldom more than 10 cm and typically include a combination of one or two species with floating stems, such as *Oxalis natans*, *O. disticha* or *Cadiscus aquaticus* plus one or two geophytes, especially *Romulea aquatica*, *R. multisulcata*, *Onixotis stricta* and *Lachenalia bachmannii*.

Geology, Soil & Hydrology Vernal pools form either on fine clays or silts overlying some impermeable layer and are thus largely restricted to Malmesbury Group shales (Namibian Erathem) and sometimes on the coastal sands derived from sandstones of the Table Mountain Group. They vary in dimension, but are mostly between 20 and 100 m in diameter. The pools are highly seasonal, filling up from May and beginning to dry out in October. The water level rarely exceeds 10 cm at the deepest point and they become completely dry in summer.

Climate Found exclusively in regions characterised by winter-rainfall (MAP range 163–430 mm). Climate is warm-temperate with MAT ranging between 16.4°C and 17.2°C. See also climate diagram for AZf 2 Cape Vernal Pools (Figure 13.2).

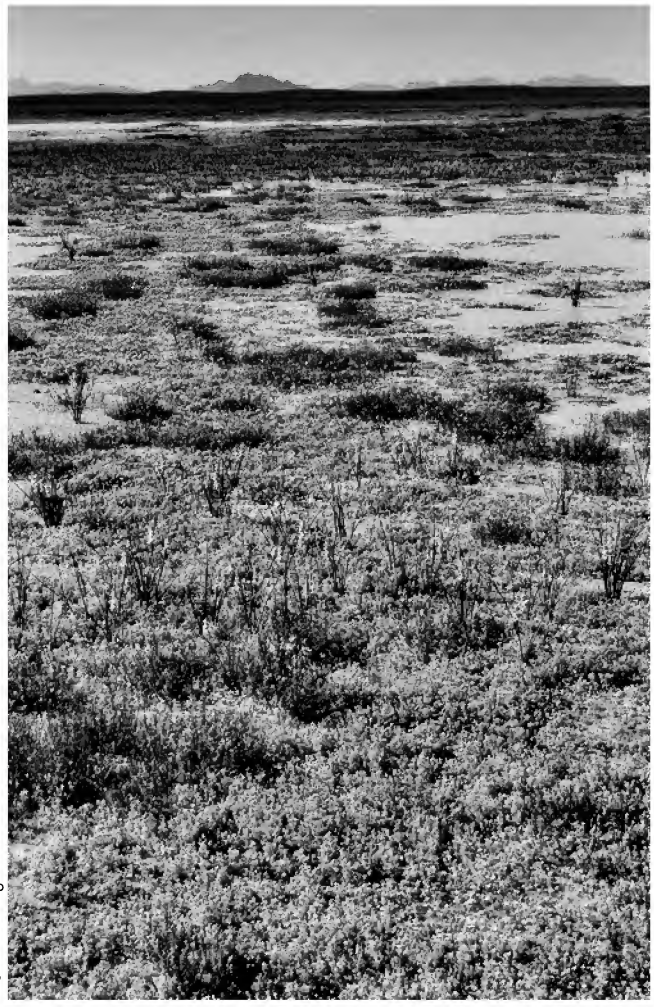
Important Taxa Herbs: *Cotula coronopifolia* (d), *Arctotheca forbesiana*, *Felicia tenella*, *Hesperantha falcata*, *Wimmerella secunda*. Geophytic Herbs: *Onixotis stricta* (d), *Ornithogalum thyrsoides* (d), *Geissorhiza aspera*, *G. juncea*, *Lachenalia aloides* var. *aloides*, *L. orchioides*, *Micranthus alopecuroides, M. plantagineus*, *Romulea rosea, R. tabularis*, *Sparaxis bulbifera*, *Spiloxene aquatica*, *Triglochin bulbosa*, *Zantedeschia aethiopica*. Succulent Herbs: *Crassula aphylla, C. decumbens*, *C. expansa, C. natans*, *C. vaillantii*. Aquatic Herb: *Limosella grandiflora*. Graminoids: *Diplachne fusca* (d), *Stenotaphrum secundatum* (d), *Cyperus tenellus*, *Isolepis diabolica*, *Schoenus nigricans, Scirpus cernuus*.

Biogeographically Important Taxon Herb: *Pilularia americana* (continental disjunction).

Endemic Taxa Graminoids: *Isoetes capensis*, *I. stellenbossiensis*, *I. stephansenii*. Herbs: *Cadiscus aquaticus* (d), *Arctotheca marginata, Cotula vulgaris*, *Marsilea schelpeana*. Geophytic Herbs: *Lachenalia bachmannii*, *Oxalis disticha*, *O. natans*, *Romulea aquatica*, *R. multisulcata*.

Conservation Critically endangered through especially cultivation and none so far conserved in statutory conservation areas. Target 24%.

Remark 1 The seasonal (vernal) pools (called 'Smaller Cyperaceae Zone' by Muir 1929, p. 70) used to be a common sight on the Cape Flats and Stellenbosch Flats in the past. Only remnants are encountered today (e.g. Campbell et al. 1980: Edith Stephens



J.C. Manning

Figure 13.16 AZf 2 Cape Vernal Pools: A flooded vernal pool near Hopefield (West Coast) with rare and endemic *Cadiscus aquaticus*, *Romulea* species and *Onixotis stricta*.

L. Mucina

Figure 13.17 AZf 2 Cape Vernal Pools: Temporary pools on hard Nardouw sandstones on the top of the Bokkeveld Plateau (Farm Meulsteen near Nieuwoudtville, Northern Cape). The vegetation is dominated by annual *Crassula aphylla* and *Cotula coronopifolia*.

Flora Reserve) and apparently many endemic taxa (tiny ephemerals or bulbous ephemeroids) supported by this special habitat are either under critical threat or have not been encountered again for a long time. A very specialised seasonal-pool habitat is formed on granite boulders and sheets (around Stellenbosch, Paarl, Darling, Langebaan and Saldanha).

Remark 2 Most of the small seasonal pools are not featured on our map due to lack of proper coverage and difficulties with featuring this vegetation unit at large (country-wide) mapping scales.

References Duthie (1929), Muir (1929), Taylor (1972), Noble & Hemens (1978), Campbell et al. (1980), Boucher (1987), Cook (2004).

AZf 3 Eastern Temperate Freshwater Wetlands

Distribution Northern Cape, Eastern Cape, Free State, North-West, Gauteng, Mpumalanga and KwaZulu-Natal Provinces as well as in neighbouring Lesotho and Swaziland: Around water bodies with stagnant water (lakes, pans, periodically flooded vleis, edges of calmly flowing rivers) and embedded within the Grassland Biome. Altitude ranging from 750–2 000 m.

Vegetation & Landscape Features Flat landscape or shallow depressions filled with (temporary) water bodies supporting zoned systems of aquatic and hygrophilous vegetation of temporarily flooded grasslands and ephemeral herblands.

Geology, Soil & Hydrology Found on younger Pleistocene to recent sediments overlying fine-grained sedimentary rocks of the Karoo Supergroup (on sediments of both Ecca and Beaufort Groups due to the large extent of the area of occurrence) as well as of the much older dolomites of the Malmani Subgroup of the Transvaal Supergroup in the northwest. Especially the areas built by Karoo Supergroup sediments are associated with the occurrence of Jurassic Karoo dolerite dykes having a profound influence on run-off. Soils are peaty (Champagne soil form) to vertic (Rensberg soil form). The vleis form where flow of water is impeded by impermeable soils and/or by erosion resistant features, such as dolerite intrusions. Many vleis and pans of this type of freshwater wetlands are inundated and/or saturated only during the summer rainfall season, and for some months after this into the middle of the dry winter season, but they may remain saturated all year round. Surface water inundation may be present at any point while the wetland is saturated and some plant species will be present only under inundated conditions, or under permanently saturated conditions. The presence of standing water should not be taken as a sign of permanent wet conditions.

Climate Exclusively summer-rainfall region (MAP range 421–915 mm). Cool-temperate pattern with MAT ranging between 12.6°C and 16.7°C. Due to high elevation, frost is a frequent phenomenon. See also the summary climate diagram for AZf 3 Eastern Temperate Freshwater Wetlands (Figure 13.2).

Important Taxa **Marshes** Megagraminoid: *Cyperus congestus* (d). Graminoids: *Agrostis lachnantha* (d), *Carex acutiformis* (d), *Eleocharis palustris* (d), *Eragrostis plana* (d), *E. planiculmis* (d), *Fuirena pubescens* (d), *Helictotrichon turgidulum* (d), *Hemarthria altissima* (d), *Imperata cylindrica* (d), *Leersia hexandra* (d), *Paspalum dilatatum* (d), *P. urvillei* (d), *Pennisetum thunbergii* (d), *Schoenoplectus decipiens* (d), *Scleria dieterlenii* (d), *Setaria sphacelata* (d), *Andropogon appendiculatus*, *A. eucomus*, *Aristida aequiglumis*, *Ascolepis capensis, Carex austro-africana*, *C. schlechteri*, *Cyperus cyperoides*, *C. distans*, *C. longus*, *C. marginatus*, *Echinochloa holubii*, *Eragrostis micrantha*, *Ficinia acuminata*, *Fimbristylis complanata*, *F. ferruginea*, *Hyparrhenia dregeana*, *H. quarrei, Ischaemum fasciculatum*, *Kyllinga erecta*, *Panicum schinzii*, *Pennisetum sphacelatum*, *Pycreus macranthus*, *P. nitidus*, *Setaria pallide-fusca*, *Xyris gerrardii*. Herbs: *Centella asiatica* (d), *Ranunculus multifidus* (d), *Berkheya radula*, *B. speciosa*, *Berula erecta* subsp. *thunbergii*, *Centella coriacea*, *Chironia palustris*, *Equisetum ramosissimum*, *Falckia oblonga*,

L. Mucina

Figure 13.18 AZf 3 Eastern Temperate Freshwater Wetlands: Small wetland sedge bed surrounded by sub-escarpment grassland in Transkei (Eastern Cape).

Haplocarpha lyrata, *Helichrysum difficile*, *H. dregeanum*, *H. mundtii*, *Hydrocotyle sibthorpioides*, *H. verticillata*, *Lindernia conferta*, *Lobelia angolensis*, *L. flaccida*, *Mentha aquatica*, *Monopsis decipiens*, *Pulicaria scabra*, *Pycnostachys reticulata*, *Rorippa fluviatilis* var. *fluviatilis*, *Rumex lanceolatus*, *Senecio inornatus*, *S. microglossus*, *Sium repandum*, *Thelypteris confluens*, *Wahlenbergia banksiana*. Geophytic Herbs: *Cordylogyne globosa*, *Crinum bulbispermum*, *Gladiolus papilio*, *Kniphofia ensifolia*, *K. fluviatilis*, *K. linearifolia*, *Neobolusia tysonii*, *Nerine gibsonii* (only in Eastern Cape), *Satyrium hallackii* subsp. *hallackii*. **Reed & sedge beds** Megagraminoids: *Phragmites australis* (d), *Schoenoplectus corymbosus* (d), *Typha capensis* (d), *Cyperus immensus*. Graminoid: *Carex cernua*. **Water bodies** Aquatic Herbs: *Aponogeton junceus*, *Ceratophyllum demersum*, *Lagarosiphon major*, *L. muscoides*, *Marsilea capensis*, *Myriophyllum spicatum*, *Nymphaea lotus*, *N. nouchali* var. *caerulea*, *Nymphoides thunbergiana*, *Potamogeton thunbergii*. Carnivorous Herb: *Utricularia inflexa*. Herb: *Marsilea farinosa* subsp. *farinosa*.

Biogeographically Important Taxon (Highveld endemic) Herb: *Rorippa fluviatilis* var. *caledonica*.

Endemic Taxa **Marshes** Geophytic Herbs: *Disa zuluensis*, *Kniphofia flammula* (northern KwaZulu-Natal), *Nerine platypetala*. Succulent Herb: *Crassula tuberella*.

Conservation Target 24%. About 5% statutorily conserved in the Blesbokspruit (a Ramsar site), Hogsback, Marievale, Olifantsvlei, Seekoeivlei (a Ramsar site), Wakkerstroom Wetland, Umgeni Vlei, Umvoti Vlei and Pamula Park Nature Reserves. It is also protected in private nature reserves such as the Korsman Bird Sanctuary and Langfontein. Some 15% has been transformed to cultivated land, urban areas or plantations. In places intensive grazing and use of lakes and freshwater pans as drinking pools for cattle or sheep cause major damage to the wetland vegetation. The following aliens are encountered in this type of wetland: *Bidens bidentata*, *Cirsium vulgare*, *Conyza bonariensis*, *Oenothera rosea*, *Physalis viscosa*, *Plantago lanceolata*, *Rumex crispus*, *Sesbania punicea*, *Schkuhria pinnata*, *Stenotaphrum secundatum* (native on South African coast, alien on highveld), *Trifolium pratense*, *Verbena bonariensis*, *V. brasiliensis*, *Xanthium strumarium*, etc.

Remarks Vegetation patterning in the form of concentric belts ('rings') is often found in pans. Pan size and depth may be a factor limiting vegetation, as large water bodies with shallow water may experience wave action. This limits the presence of species with floating leaves as well as some submerged and marginal macrophytes. The situation is more complex in vleis as these often have variable microtopography and soil types within a single wetland. It is possible for seasonally inundated zones to occur embedded inside the permanently inundated zone of a vlei, if this zone is present.

References Downing (1966, 1968, 1970), Noble & Hemens (1978), Müller (1986), Allan (1987), Begg & Carser (1988, 1989), Behr & Bredenkamp (1988), Breytenbach (1991), Fuls et al. (1992), Breen et al. (1993), Breytenbach et al. (1993), Eckhardt (1993), Eckhardt et al. (1993a, c), Smit et al. (1993a, 1995, 1997), Bredenkamp et al. (1994), Coetzee et al. (1994a, b), Malan (1997), Cilliers et al. (1998), Kotze & O'Connor (2000), Perkins et al. (2000), Van Wyk et al. (2000), Dingaan et al. (2001), Siebert et al. (2002), Malan (2003).

AZf 4 Drakensberg Wetlands

Including 'Wetlands below escarpment' (Hilliard & Burtt 1987).

Distribution Free State, KwaZulu-Natal, Eastern Cape and Mpumalanga Provinces as well as in Lesotho: Wetlands (vleis and lakes) on broad ridges and narrow alluvia of slow- and fast-flowing mountain streams in deeply incised valleys. Found from the Stormberg Plateau through the highlands of the Eastern Cape, KwaZulu-Natal and Lesotho (Drakensberg range). Outliers occur also on top of tafelbergs such as Korannaberg, Thaba Nchu and Platberg. Scattered along the Low Escarpment (between Van Reenen's Pass and Piet Retief) and then along the Northern Escarpment. The northernmost patch of this wetland type has thus far been identified on the summit plateau of the Leolo Mountains in Sekhukhuneland. Embedded within the high-altitude Grassland Biome found at altitudes roughly spanning 1 800–2 500 m.

Vegetation & Landscape Features Vleis (sometimes with open water bodies such as tarns) and fringes of mountain streams, supporting tall herb vegetation and shrubby vegetation of medium height (reaching thicket density in places) along upper reaches of mountain streams. Characteristic feature of the Drakensberg Wetlands is the frequent occurrence of terrestrial orchids and species of *Kniphofia* and *Geranium*.

Geology, Soil & Hydrology Geological substrate is formed by the uppermost (youngest) part of the Karoo Supergroup. Jurassic basalts and dolerites of the Drakensberg Group as well as sandstones and mudstones of the Clarens and Elliot Formations (both Triassic) forming the Eastern Escarpment. These bedrocks support heavy, clayey soils (e.g. Champagne, Arcadia, Katspruit soil forms) often with high humus content. The water bodies are either stagnant (or slow-flowing) and fed either from springs or slope seeps or to an extent also from abundant rainfall and snowfall (especially in the Eastern Cape). Here we have also included vegetation along fast-flowing mountain streams in sandy gravel and stony (in places built of large boulders) ravines with only very narrow alluvia—the habitats along the fast-flowing streams can suffer extensive erosion, especially during heavy-rainfall and stormy local weather situations in summer. Some water bodies freeze in winter.

Climate Seasonal, summer-rainfall regime with maximum precipitation in December–February (MAP range 543 mm on

K. Kobisi

Figure 13.19 AZf 4 Drakensberg Wetlands: Riparian vegetation (with dominant *Leucosidea sericea*) along a stream in a Tšehlanyane gorge in northern Lesotho.

Stormberg Plateau, up to 1 247 mm on upper uKhahlamba). Especially on the Southern Berg, part of this precipitation occurs in the form of snow. Sudden melting of the snow cover on the surrounding high-altitude grasslands may have a profound (albeit short-term) influence on stream flow and may subsequently cause erosion of the river channels. The temperature regime is cold-temperate with MAT spanning 9.6°C (Lesotho Plateau) to 13.1°C (Senqu Valley). See also regional climate diagram for AZf 4 Drakensberg Wetlands (Figure 13.2).

Important Taxa **Drainage-line grasslands & herblands** Tree Fern: *Cyathea dregei* (d). Megagraminoid: *Miscanthus junceus* (d). Graminoids: *Cyperus congestus* (d), *Merxmuellera macowanii* (d), *Cyperus keniensis*, *C. marginatus, C. usitatus, Hyparrhenia quarrei, Pycreus mundii*. Herbs: *Peltocalathos baurii* (d), *Epilobium salignum*, *Geranium wakkerstroomianum*, *Nasturtium officinale*. Geophytic Herbs: *Gunnera perpensa* (d), *Galtonia candicans*, *G. princeps*, *Littonia modesta*, *Neobolusia tysonii, Sandersonia aurantiaca*. **Drainage-line shrublands** Tall Shrubs: *Buddleja salviifolia* (d), *Cliffortia linearifolia* (d), *Leucosidea sericea* (d), *Cliffortia nitidula*, *Phygelius aequalis*. Low Shrubs: *Cliffortia filicauloides*, *Erica oatesii*, *Senecio subrubriflorus*. Herbs: *Denekia capensis*, *Persicaria meisneriana*, *Salvia aurita*. **Marshes & seeps** Graminoids: *Carex acutiformis* (d), *C. austro-africana* (d), *Fuirena pubescens* (d), *Ascolepis capensis, Carex cognata*, *Carpha filifolia*, *Helictotrichon turgidulum, Juncus oxycarpus*, *Kyllinga pauciflora, Rhynchospora brownii*, *Schoenoxiphium burttii*, *Scirpus ficinioides*, *Xyris capensis*, *X. gerrardii*. Herbs: *Ranunculus meyeri* (d), *R. multifidus* (d), *Epilobium capense*, *Eriocaulon hydrophilum*, *Pycnostachys reticulata*, *Rumex lanceolatus*, *Senecio serratuloides*. Geophytic Herbs: *Dierama pauciflorum*, *Drimia sphaerocephala*, *Kniphofia albescens*, *K. fluviatilis*, *K. linearifolia*, *K. northiae*, *K. triangularis*, *Moraea ardesiaca*, *M. trifida*, *Nerine angustifolia, N. gibsonii* (only in Eastern Cape), *Satyrium hallackii* subsp. *hallackii*, *S. trinerve*, *Schizoglossum nitidum*, *Zantedeschia albomaculata*. **Streams** Graminoid: *Isolepis fluitans*. Aquatic Herb: *Hydrophilus rattrayi*. **Tarns** Aquatic Herbs: *Limosella africana*, *L. inflata*. Carnivorous Herb: *Utricularia prehensilis*. Succulent Herb: *Crassula natans*. Graminoids: *Juncus dregeanus*, *J. punctorius*. Herbs: *Lindernia bolusii*, *L. conferta*.

Biogeographically Important Taxa (all Drakensberg endemic): **Drainage-line grasslands & herblands** Herb: *Geranium pulchrum*. Geophytic Herb: *Anemone fanninii*. **Marshes** Herbs: *Cotula paludosa*, *Felicia uliginosa*, *Gnaphalium limicola*. Geophytic Herb: *Wurmbea elatior*.

Endemic Taxa **Drainage-line shrublands** Herbs: *Afrotysonia africana*, *A. glochidiata*, *Felicia drakensbergensis, Lepidium basuticum*, *Sebaea pleurostigmatosa*, *Senecio kalingenwae*. **Marshes & seeps** Graminoid: *Isolepis pellocolea*. Herb: *Helichrysum ephelos*. Geophytic Herbs: *Disa scullyi*, *Kniphofia albomontana*, *K. evansii*.

Conservation Target 24%, but already almost perhaps more than 50% conserved in statutory protection areas such as the uKhahlamba Drakensberg Park (a Ramsar site), and Sehlabathebe and Tšehlanyane National Parks and Bokong Nature Reserve (all Lesotho). Only about 2–3% has been transformed for cultivation. Invasive aliens do not play any important role.

Remarks This unit has not been mapped in its full extent due to a lack of data, particularly for riparian shrubland, which deserves recognition as a vegetation unit in its own right (as an analogue to the AZa 1 Fynbos Riparian Vegetation). Important patches of the riparian thickets occur along many Drakensberg (including many deeply incised river valleys in Lesotho), Amathole and possibly also Stormberg mountain streams. In the Low Drakensberg area similar vegetation was found to occur in places even below 1 800 m (Smit et al. 1995). Due to lack of data we did not map the patches of this wetland along the Eastern Escarpment and adjacent mountain ranges (see Burgoyne 1995, Burgoyne et al. 2000).

References Bews (1917), Jacot Guillarmod (1964, 1969, 1972), Nanni (1972), Smith (1972), Killick (1978a, b), Noble & Hemens (1978), Potgieter (1982), Deall (1985), Hilliard & Burtt (1987), Begg & Carser (1989), Deall et al. (1989), Killick & Holcroft (1990), Du Preez (1991), Du Preez & Bredenkamp (1991), Matthews (1991), Matthews et al. (1992), Smit et al. (1993b, 1995), Burgoyne (1995), Dely et al. (1995), Eckhardt et al. (1996), Eckhardt (1998), Burgoyne et al. (2000), Siebert et al. (2002), http://www.ngo.grida.no/soesa/nsoer/resource/wetland/sa_ramsar.htm.

AZf 5 Lesotho Mires

Distribution Lesotho and to a very small extent also South Africa (KwaZulu-Natal Province): Lesotho Plateau and adjacent mountain ranges—wetlands (locally, in Sesotho, called 'mokhoabo') embedded within grassland units Gd 10 Drakensberg Afroalpine Heathland and upper parts of Gd 8 Lesotho Highland Basalt Grassland. Altitude ranging from 2 500–3 400 m.

Vegetation & Landscape Features Depressions and slight slopes on the high-altitude plateau. Low grass-herb mire complexes with turf and tussock grassland patches and herblands built of low creeping herbs as well as luxurious moss cover in places. Small lakes (tarns) support aquatic vegetation covering tarn bottoms where shallow water column allows deep penetration of light.

M. Polaki

Figure 13.20 AZf 5 Lesotho Mires: Complex of low-altitude mires on Thaba Putsoa in western Lesotho.

Geology, Soil & Hydrology Peat (organic soils) functioning as sponge in summer and freezing in winter over basaltic lava flows of the Jurassic Drakensberg Group (top of the Karoo Supergroup). Eutrophic water rich in CaO, K_2O and P_2O_3 with pH about 8 (Stockley 1947 *sec.* Van Zinderen Bakker & Werger 1974), changing in an oligotrophic direction, with ultimate values between pH 4 and 5. Most of the pH (H_2O) measurements of soils by Backéus (1988) in the Thaba-Putsoa range were below 5.

Climate Seasonal, summer-rainfall regime with MAP 1 500 mm, much of it in the form of snow. Very cold, high-altitude climate (MAT 4.0–9.6°C); according to Van Zinderen Bakker & Werger (1974) the maximum temperatures in summer do not exceed 16°C, while the nightly minimum temperature at soil level is below freezing point throughout the year. See also climate diagram for AZf 5 Lesotho Mires (Figure 13.2).

Important Taxa **Mires** Semiparasitic Shrub: *Thesium nigrum*. Graminoids: *Agrostis bergiana* var. *bergiana* (d), *Carex cognata* (d), *Isolepis costata* (d), *Kyllinga erecta* (d), *Scirpus ficinioides* (d), *Agrostis lachnantha*, *Bulbostylis densa*, *Juncus dregeanus*, *Koeleria capensis*, *Luzula africana*, *Pennisetum thunbergii*. Herbs: *Athrixia fontana* (d), *Haplocarpha nervosa* (d), *Ranunculus meyeri* (d), *Alchemilla woodii*, *Anagallis huttonii*, *Cerastium capense*, *Cineraria lyrata*, *Cotula hispida*, *Eriocaulon sonderianum*, *Lobelia flaccida*, *Ranunculus multifidus*, *Rorippa microphylla*, *Sebaea leiostyla*, *Senecio macrocephalus*, *S. polyodon* var. *subglaber*, *Trifolium burchellianum*. Geophytic Herbs: *Ornithogalum paludosum*, *Oxalis obliquifolia*, *Rhodohypoxis milloides*, *Wurmbea kraussii*. Carnivorous Herb: *Utricularia livida*. **Tarns** Succulent Herbs: *Crassula inanis* (d), *C. natans* (d). Aquatic Herbs: *Lagarosiphon muscoides* (d), *Limosella longiflora* (d), *L. maior* (d), *Aponogeton junceus*, *Limosella africana*, *L. vesiculosa*.

Biogeographically Important Taxa (all Drakensberg endemic): **Mires** Low Shrubs: *Erica frigida*, *Inulanthera thodei*. Graminoids: *Agrostis subulifolia*, *Carex monotropa*, *Fuirena tenuis*, *Schoenoxiphium filiforme*. Herbs: *Senecio cryptolanatus* (d), *Alepidea pusilla*, *Cotula paludosa*, *Felicia uliginosa*, *Helichrysum bellum*. Geophytic Herbs: *Rhodohypoxis deflexa*, *R. rubella*, *Saniella verna*, *Wurmbea elatior*. Succulent Herb: *Crassula gemmifera*. **Tarns** Aquatic Herb: *Limosella inflata*.

Endemic Taxa **Mires** Semiparasitic Shrub: *Thesium nationae*. Graminoids: *Isolepis angelica* (d), *Colpodium hedbergii*. Herbs: *Helichrysum flanaganii*, *Sebaea marlothii*. Geophytic Herbs: *Kniphofia caulescens* (d), *Hesperantha crocopsis*, *Romulea luteoflora* var. *sanisensis*. **Tarns** Aquatic Herb: *Aponogeton ranunculiflorus* (d).

Conservation Target 24%. Only about 4% statutorily conserved in the Malekgonyane (Ongeluksnek) Wildlife Reserve and uKhahlamba Drakensberg Park (a Ramsar site) and in the Bokong Nature Reserve (Lesotho). Grazing (and even burning) can be seen as a serious threat to this unique and fragile vegetation type.

References Bews (1917), Van Zinderen Bakker (1955, 1965), Jacot Guillarmod (1961, 1962, 1963, 1964, 1968, 1971, 1972), Van Zinderen Bakker & Werger (1974), Killick (1978a, b), Backéus (1988), Schwabe (1989, 1995), Du Preez (1991), Du Preez & Bredenkamp (1991), Lesotho Government, National Environment Secretariat (2000), Day (2005a), http://www.ngo.grida.no/soesa/nsoer/resource/wetland/sa_ramsar.htm.

AZf 6 Subtropical Freshwater Wetlands

Distribution KwaZulu-Natal, Mpumalanga, Gauteng, North-West, Limpopo and Eastern Cape Provinces as well as in Swaziland: Wetlands embedded within the Albany Thicket Biome, the Coastal Belt from Transkei as far as Maputaland as well as those of Lowveld and the Central Bushveld regions. Altitude ranging from 0–1 400 m.

Vegetation & Landscape Features Flat topography supporting low beds dominated by reeds, sedges and rushes, waterlogged meadows dominated by grasses. Found typically along edges of often seasonal pools in aeolian depressions as well as fringing alluvial backwater pans or artificial dams.

Geology, Soil & Hydrology Waterlogged, clayey soils of Champagne and Arcadia forms, containing certain levels of decaying organic matter, especially in very productive reed beds. These wetlands are underlain mostly by Cenozoic alluvium, less so by Karoo Supergroup volcanic rocks and sediments, as well as by the Cretaceous (and younger coastal) sediments of the Zululand and Maputaland Groups. Waterlogged habitats with water regularly forming columns of variable depth. The highest water levels are found in summer, during periods of maximum seasonal rainfall.

Climate Mainly seasonal, summer rainfall (Lowveld and Central Bushveld), and to a lesser extent also nonseasonal (Albany region and the Eastern Cape and KwaZulu-Natal coastal belts) climate characterised by high precipitation. MAP spanning 454 mm (Makhado) to 963 mm (Maputaland). Subtropical and tropical temperature regimes are prevalent in winter and summer, respectively. MAT ranging from 18.0°C (Central Bushveld) to 22.0°C (Makatini Flats). Occurrence of frost is limited to southernmost localities. See also climate diagram for AZf 6 Subtropical Freshwater Wetlands (Figure 13.2).

W.S. Matthews

Figure 13.21 AZf 6 Subtropical Freshwater Wetlands: Muzi Swamp in an interdune depression at the edge of the Tembe Elephant Park on the Mozambique border (northern KwaZulu-Natal). The reed beds of *Phragmites mauritianus* dominant in the swamp are surrounded by broad-leaved savanna of the SVl 18 Tembe Sandy Bushveld.

Important Taxa **Marshes** Small Trees: *Hyphaene coriacea* (d), *Phoenix reclinata* (d). Graminoids: *Chloris virgata* (d), *Cynodon dactylon* (d), *Cyperus articulatus* (d), *Dactyloctenium aegyptium* (d), *Diplachne fusca* (d), *Echinochloa pyramidalis* (d), *Fimbristylis obtusifolia* (d), *Hemarthria altissima* (d), *Imperata cylindrica* (d), *Ischaemum arcuatum* (d), *Leersia hexandra* (d), *Pycreus mundii* (d), *Sporobolus nitens* (d), *S. smutsii* (d), *Urochloa stolonifera* (d), *Bolboschoenus glaucus, Courtoisia cyperoides*, *Cyperus alopecuroides*, *C. pectinatus*, *Digitaria natalensis*, *Echinochloa stagnina*, *Eragrostis chapelieri, E. lappula, Eriochloa meyeriana*, *Fimbristylis bisumbellata*, *Fuirena ecklonii*, *Oxycaryum cubense*, *Paspalidium obtusifolium*, *Paspalum commersonii*, *Pycreus pelophilus*, *P. polystachyos*, *Scleria poiformis*, *Sporobolus consimilis*. Herbs: *Pentodon pentandrus* (d), *Persicaria senegalensis* (d), *Burmannia madagascariensis, Centella coriacea*, *Commelina diffusa, Convolvulus mauritanicus*, *Desmodium dregeanum*, *Eclipta prostrata, Epaltes gariepina*, *Eriocaulon abyssinicum*, *Ethulia conyzoides*, *Glinus lotoides*, *Hydrocotyle ranunculoides, Ludwigia adscendens* subsp. *diffusa*, *L. leptocarpa*, *L. octovalvis*, *L. palustris*, *Neptunia oleracea*, *Persicaria attenuata* subsp. *africana, P. hystricula*, *Rorippa madagascariensis*, *Sium repandum*, *Vahlia capensis*. Geophytic Herbs: *Eulophia angolensis*, *Zeuxine africana*. Succulent Herb: *Salicornia pachystachya*. Semiparasitic Herb: *Buchnera longespicata*. Aquatic Herbs: *Bergia salaria*, *Lagarosiphon crispus*. **Lakes & ponds** Graminoid: *Eleocharis dulcis* (forming rafts). Aquatic Herbs: *Azolla pinnata* var. *africana* (d), *Ceratophyllum demersum* (d), *Lemna minor* (d), *Nymphaea nouchali* var. *caerulea* (d), *Pistia stratiotes* (d), *Wolffia arrhiza* (d), *Aponogeton desertorum, A. natalensis, A. rehmannii, Ceratophyllum muricatum*, *Marsilea macrocarpa*, *Najas marina* subsp. *delilei*, *N. pectinata*, *Nymphoides indica* subsp. *occidentalis*, *N. rautanenii*, *Ottelia exserta*, *Potamogeton crispus*, *P. pectinatus*, *P. schweinfurthii*, *Spirodela polyrhiza*, *S. punctata, Trapa natans* var. *bispinosa*. Carnivorous Herbs: *Utricularia gibba* subsp. *exoleta*, *U. inflexa*, *U. subulata*. Geophytic Herb: *Crinum paludosum*. **Reed & sedge beds** Megagraminoids: *Cladium mariscus* subsp. *jamaicense* (d), *Cyperus papyrus* (d), *Phragmites australis* (d), *P. mauritianus* (d), *Schoenoplectus corymbosus* (d), *S. scirpoideus* (d), *Typha capensis* (d). Graminoids: *Cyperus fastigiatus* (d), *C. difformis*, *C. digitatus, C. latifolius*, *C. sexangularis*, *Fuirena ciliaris*.

L. Mucina

Figure 13.22 AZf 6 Subtropical Freshwater Wetlands: Pan wetland in the Kruger National Park infested by *Pistia stratiotes* (Araceae), with a crocodile (*Crocodilus niloticus*) basking after a meal on the opposite side of the lake.

Biogeographically Important Taxa (all southernmost distribution limit) **Streambanks** Herb: *Floscopa glomerata, Ipomoea aquatica.* Geophytic Herb: *Bolbitis heudelotii*. **Lakes & ponds** Aquatic Herbs: *Brasenia schreberi*, *Ceratopteris cornuta, Wolffia globosa, Wolffiella welwitschii*. Herbs: *Hygrophila schulli, Limnophyton obtusifolius, Marsilea apposita, M. coromandelina, M. minuta*, *M. villifolia.* **Reed & sedge beds** Graminoids: *Cyperus dives, C. procerus, C. prolifer.*

Endemic Taxa **Marshes** Graminoid: *Cyperus sensilis* (embedded within Indian Ocean Coastal Belt of KwaZulu-Natal). **Lakes & ponds** Geophytic Herbs: *Crinum campanulatum* (Albany region). Aquatic Herbs: *Isoetes wormaldii* (Albany region), *Wolffiella denticulata* (Maputaland).

Conservation Least threatened. Target 24%. Some 40–50% is statutorily conserved in the Greater St Lucia Wetland Park (including Ramsar sites such as St Lucia System, Kosi Bay System and Lake Sibaya), Kruger National Park, Ndumo Game Reserve, Tembe Elephant Park as well as in Nhlabane, Nylsvley (a Ramsar site), Mkombo, Sileza and Richards Bay Nature Reserves. A further 10% enjoys protection in a number of private game farms and other reserves in the Limpopo, Mpumalanga and KwaZulu-Natal Provinces. So far only about 4% has been transformed (largely for cultivation), but the pressure of local grazing and urban sprawl will result in the demise of many subtropical freshwater habitats. Disturbance leads to invasion by alien plants such as *Lantana camara*, *Chromolaena discolor* and *Melia azedarach* (on the edges of wetlands) and aquatic weeds such as *Eichhornia crassipes*, *Pistia stratiotes* and *Salvinia molesta* (in water bodies).

References Dyer (1937), Edwards (1967), Musil (1972), Venter (1972), Musil et al. (1973), Theron (1973), Noble & Hemens (1978), Howard-Williams (1979, 1980a), Furness & Breen (1980), Heeg et al. (1980), Rogers (1980, 1984), Furness (1981), Gertenbach (1983), Tinley (1985), Goodman (1987a, b), Tarboton (1987), Begg & Carser (1988, 1989), Breen et al. (1993), Brown & Bredenkamp (1994), Barnes et al. (2002), Hattingh & Matthews (2003), http://www.ngo.grida.no/soesa/nsoer/resource/wetland/sa_ramsar.htm.

Alluvial Vegetation

Aza 1 Fynbos Riparian Vegetation

Including *Brabejum–Rhus* Riverine Scrub (Boucher 1978). *Elegia capensis–Miscanthus capensis* Scrub & *Calopsis paniculata–Cliffortia strobilifera* Scrub (Cleaver et al. 2005).

Distribution Western Cape and (partly) Eastern Cape Provinces: Vegetation of narrow belts of alluvial thickets and accompanying palmiet (*Prionium serratum*) vegetation along upper stretches of the rivers draining mountain fynbos. Altitude from near sea level to 1 300 m.

Vegetation & Landscape Features Narrow, flat or slightly sloping alluvial flats supporting a complex of reed beds dominated by tall palmiet (*Prionium serratum*) and restios (*Calopsis*, *Cannomois*, *Elegia*, *Ischyrolepis* and *Rhodocoma*), low shrublands with moisture-loving species of *Berzelia*, *Cliffortia*, *Helichrysum* etc. With tall riparian thickets of *Metrosideros angustifolia* and *Brachylaena neriifolia* in places.

L. Mucina

Figure 13.23 AZa 1 Fynbos Riparian Vegetation: Boulders along a narrow alluvium of a mountain stream in the Hottentots Holland Nature Reserve near Grabouw, with palmiet (*Prionium serratum*) in the river channel and *Brachylaena neriifolia* (Asteraceae) and *Ischyrolepis subverticillata* (Restionaceae) on the river terrace.

Geology, Soil & Hydrology Alluvial sandy or silty soils over Quaternary sediments, largely derived from weathering of Table Mountain sandstone, Cape Supergroup shale and Cape Granite. The streams are fed mainly during the winter-rainfall season and later through seeps carrying acidic water rich in organic compounds (tannins) and with a characteristic brownish colour (locally called 'tea-water'). Large streams carry water all year round, while some smaller streams can turn into a series of disconnected pools in the upper reaches in summer. Even in relatively small streams flooding can be quite violent, with strong flows especially in narrow gorges. Many trees and shrubs are adapted to uprooting or heavy damage by spates. The heavy erosion also results in a soil-poor substrate and plant cover is often very patchy, located in small depressions with some soil development or between boulders.

Climate Similar to the climate of the surrounding mountains (see climate diagrams for mesic types of fynbos such as those of the FFs and FFh groups; see the chapter on Fynbos in this book), although the presence of a river influences the microclimate of the valley considerably, making it cooler, moister and better sheltered from wind. The most detailed study on the climate in a river valley (Jonkershoek) was published by Wicht et al. (1969). (See also climate diagram in Figure 13.2.)

Important Taxa (CEndemic to Capensis, PSharing with Pondoland) Small Trees: *Brabejum stellatifolium*[C] (d), *Brachylaena neriifolia*[C] (d), *Cunonia capensis*[C] (d), *Kiggelaria africana*, *Pseudoscolopia polyantha*[P], *Widdringtonia nodiflora*. Tall Shrubs: *Berzelia lanuginosa*[C] (d), *Cliffortia strobilifera* (d), *Metrosideros angustifolia*[C] (d), *Psoralea pinnata*[C] (d), *Berzelia squarrosa*[C], *Cassine schinoides*[C], *Cliffortia atrata*[C], *Diospyros glabra*[C], *Erica caffra*, *Freylinia lanceolata*, *Halleria elliptica*[C], *Maytenus oleoides*, *Podalyria calyptrata*[C], *Psoralea aphylla*[C]. Low Shrubs: *Helichrysum cymosum*, *H. helianthemifolium*[C], *Penaea cneorum*[C], *Pseudobaeckea africana*[C]. Semiparasitic Shrub: *Osyris compressa* (d). Woody Climber: *Asparagus scandens*. Megagraminoids: *Prionium serratum*[P] (d), *Calopsis paniculata* (d), *Ischyrolepis subverticillata*[C] (d), *Cannomois virgata*[C], *Ehrharta rehmannii*, *Elegia capensis*[C], *Merxmuellera cincta*, *Miscanthus capensis*, *Rhodocoma capensis*[C]. Graminoids: *Ficinia brevifolia* (d), *Isolepis digitata*[C], *Juncus capensis*, *Pentaschistis curvifolia*, *P. pallida*, *Tetraria cuspidata*. Herbs: *Grammatotheca bergiana*[P], *Persicaria decipiens*. Geophytic Herbs: *Wachendorfia thyrsiflora*[C] (d), *Blechnum punctulatum*, *Disa tripetaloides*[P], *Osmunda regalis*, *Pteridium aquilinum*, *Todea barbata*. Carnivorous Herbs: *Drosera capensis*[C], *Utricularia bisquamata*.

Endemic Taxa Tall Shrub: *Ixianthes retzioides*. Low Shrub: *Metalasia riparia*. Herb: *Pelargonium pseudoglutinosum*. Graminoid: *Isolepis digitata* (d; aquatic). Moss: *Wardia hygrometrica* (aquatic; representative of monotypic endemic family).

Conservation Due to a very extensive system of nature reserves and wilderness areas administered by CapeNature, Eastern Cape Nature Conservation Service and partly also by South African National Parks (especially in the southern Cape), many patches of this vegetation type are well protected. This vegetation is, however, prone to infestation by alien woody plants such as *Acacia mearnsii*.

Remark 1 Due to the small scale as well as lack of data, the current mapping coverage of the unit on the national vegetation map is only a rough indication of its occurrence (few patches in the Cederberg area). The riparian thickets and accompanying palmiet reeds occur regularly along the fynbos mountain streams in many of the Cape Fold Mountains (from the Bokkeveld Plateau as far as Van Stadens Mountains near Port Elizabeth), and we hope they will receive proper attention in future. Many important species of riparian scrub vegetation do not occur east of Mossel Bay.

Remark 2 This vegetation unit bears floristic (and partly also ecological) similarity to the Western Cape Talus Forest (subtype: Western Cape Riverine Forests) of Von Maltitz et al. (2003) and Geldenhuys & Mucina (2006)—well-developed riparian forests along several rivers of the Cape Fold Mountains.

References Marloth (1908), Rycroft (1953), Harrison & Elsworth (1958), Martin & Noel (1960), Grobler (1964), Harrison (1964), Wicht et al. (1969), Boucher (1972, 1978, 1987, 1994, 1996a, 1999a, b), Werger et al. (1972a, b), Kruger (1974, 1979), Campbell (1975), Acocks (1976), Linder (1976), Le Roux (1977), Priday (1977), Van Zyl (1977), Parkman (1978), Taylor (1978), Seydack & Home (1980), McDonald (1985, 1988), Van Wilgen & Kruger (1985), Sieben (2003), Cleaver et al. (2005).

AZa 2 Cape Lowland Alluvial Vegetation

Riparian vegetation p.p. (Boucher 1978).

Distribution Western Cape Province: Vegetation of broad alluvia of middle and lower stretches of rivers of the Western Cape such as the upper Olifants, Berg, Eerste, Lourens, Palmiet, Bot, Klein, Breede, Goekoe, Gouritz, Hartebeeskuil, Klein Brak, Groot Brak, Keurbooms and a number of small tributaries of the above-mentioned water courses. Altitude ranging from 20–300 m.

L. Mucina

Figure 13.24 AZa 2 Cape Lowland Alluvial Vegetation: Bottom of temporary water course feeding into Verlorenvlei Lake, with *Phragmites australis* reed bed near Redelinghuys (Western Cape).

Vegetation & Landscape Features Flat landscape with slow-flowing (in place meandering) lowland rivers fringed on banks by extensive tall reeds dominated by *Phragmites australis* and *Typha capensis* as well as by flooded grasslands and herblands and tall riparian thickets (gallery forests) with *Salix mucronata* subsp. *capensis* on the river terraces.

Geology, Soil & Hydrology Alluvial fine sandy, silty and clayey soils over Quaternary sediments, largely derived from weathering of Table Mountain sandstone, Bokkeveld Group shales and Cape Granite (specifically the George Batholith). The streams are fed mainly during the winter-rainfall season. An important factor on the flood regime are the numerous dams built for water storage, which can simulate features of a natural flood regime by means of several quick releases of water from the reservoir.

Climate Identical to the climate of the surrounding lowland vegetation, and due to the large geographical span of the scattered patches of this vegetation unit, it typically encompasses winter rainfall as well as transitional winter-summer rainfall in both facies (with prevalence of either). The local MAP spans 320 mm (Breede River Valley) to 700 (Garden Route) while the MAT spans 15.9°C (Overberg) to 17.2°C (Garden Route). See also climate diagram for AZa 2 Cape Lowland Alluvial Vegetation (Figure 13.2).

Important Taxa ([C]Endemic to Capensis, [P]Sharing with Pondoland) **Riparian thickets** Small Trees: *Salix mucronata* subsp. *mucronata* (d), *Virgilia divaricata*[C], *Podocarpus elongatus*[C]. Tall Shrubs: *Buddleja saligna, B. salviifolia*, *Cliffortia strobilifera*, *Freylinia lanceolata*, *Rhus angustifolia*. Low Shrubs: *Cliffortia odorata* (d), *Senecio halimifolius* (d), *Cliffortia ferruginea*[C]. **Flooded grasslands & herblands** Tall Shrub: *Melianthus major* (d). Megagraminoids: *Prionium serratum*[P] (d), *Calopsis paniculata*, *Cyperus thunbergii*. Graminoids: *Cynodon dactylon* (d), *Cyperus congestus, C. denudatus*, *C. textilis*, *Eragrostis sarmentosa*, *Ficinia distans*, *Fuirena hirsuta*, *Hemarthria altissima*, *Isolepis cernua*, *I. prolifera*, *Juncus capensis*, *J. lomatophyllus*, *Leersia hexandra*, *Merxmuellera cincta*, *Paspalum distichum*, *Pennisetum macrourum*. Herbs: *Conyza scabrida*, *Helichrysum helianthemifolium*[C], *Laurembergia repens, Persicaria decipiens*. Geophytic Herbs: *Wachendorfia thyrsiflora*[C] (d), *Triglochin bulbosa* complex, *Watsonia galpinii*[C], *Zantedeschia aethiopica*. **Open water** Aquatic Herb: *Myriophyllum spicatum*.

Endemic Taxon **Riparian thickets** Small Tree: *Salix mucronata* subsp. *hirsuta* (d; only Olifants River and maybe Berg River catchments; see Jordaan 2005).

Conservation Critically endangered. Target 31%, but so far only about 1% statutorily (Bontebok National Park, Verlorenvlei (a Ramsar site), Broomvlei, Marloth Nature Reserves) or privately (Wadrif) conserved. Some 72% of the area has been transformed for cultivation, urban development and road building. Disturbance and alien infestation are very common in this type. Among the most vigorous woody alien invaders are *Acacia saligna*, *A. mearnsii* and *A. longifolia* as well as *Alnus glutinosa*, *Quercus robur*, *Salix babylonica* and *Sesbania punicea*. The high nutrient status of alluvial soils attracts fast-growing herbaceous alien weeds such as *Xanthium* species, *Sonchus oleraceus*, *Rumex crispus*, *Stellaria media* etc. as well as garden escapes such as *Tropaeolum majus*, *Tradescantia fluminensis*, *Pennisetum clandestinum* (kikuyu grass), *Colocasia esculenta* and *Lupinus angustifolius* (see for instance Duvenhage 1993 and Ahmed 1995).

References Duthie (1929), Muir (1929), Stephens (1929), Harrison & Elsworth (1958), Harrison (1964), Grobler & Marais (1967), Acocks (1976), Boucher (1978, 1987, 1996a, b, 1997), Noble & Hemens (1978), Rebelo et al. (1991), Duvenhage (1993), Ahmed (1995), Sieben (2003), http://www.ngo.grida.no/soesa/nsoer/resource/wetland/sa_ramsar.htm.

AZa 3 Lower Gariep Alluvial Vegetation

Distribution Northern Cape Province: Broad alluvium (floodplains and islands) of the Orange (Gariep) River between Groblershoop and the mouth into the Atlantic Ocean at Oranjemund (Namibia). This river stretch is embedded within Desert (Oranjemund to roughly Pofadder) and Nama-Karoo (further upstream as far as Groblershoop). Altitude ranging from 0–1 000 m.

Vegetation & Landscape Features Flat alluvial terraces and riverine islands supporting a complex of riparian thickets (dominated by *Ziziphus mucronata*, *Euclea pseudebenus* and *Tamarix usneoides*), reed beds with *Phragmites australis* as well as flooded grasslands and herblands populating sand banks and terraces within and along the river.

Geology, Soil & Hydrology Recent alluvial deposits of the Orange River supporting soil forms such as Dundee and Oakleaf. The river cuts through a great variety of Precambrian metamorphic rocks. Ia land type. Subject to floods, especially in summer, caused by high precipitation on the highveld.

Climate Region with very arid (desert) to subarid (semidesert) climate and erratic, unimodal (winter-rainfall) regime in the extreme west (near the Orange River mouth) to bimodal, equinoctial with major peak in March and less pronounced peak in November in the extreme east (near Upington). MAP 40–150 mm and MAT between 15.4°C (Alexander Bay) and 20.5°C (Upington). See also climate diagram for AZa 3 Lower Gariep Alluvial Vegetation (Figure 13.2).

L. Mucina

Figure 13.25 AZa 3 Lower Gariep Alluvial Vegetation: Alluvial grasslands with *Cynodon dactylon* and riparian thickets with *Tamarix usneoides* on rocky banks of the Orange River at Grasdrif (Richtersveld National Park).

These river stretches are surrounded by vegetation units of broad transitional regions between the dry facies of the Savanna and Grassland and northern regions of the Nama-Karoo Biome. Altitude ranging from 1 000–1 500 m.

Vegetation & Landscape Features Flat alluvial terraces supporting complex of riparian thickets (gallery forests) dominated by native *Acacia karroo* and *Diospyros lycioides*, flooded grasslands, reed beds and ephemeral herblands populating mainly sand banks within the river and on its banks.

Geology, Soil & Hydrology Recent alluvial deposits underlain mostly by Karoo Supergroup sediments and tillites, supporting soils typical of Ia group land types. Subject to flooding, especially in summer.

Climate Bimodal (equinoctial) climate with a major peak in March and with a lesser peak in November–December. The overall MAP is 325 mm (range 230–600 mm for Prieska and Wepener, respectively). MAT for the entire area averages 17°C (range 19.3–15.4°C for Prieska and Aliwal North, respectively). See also climate diagram for AZa 4 Upper Gariep Alluvial Vegetation (Figure 13.2).

Important Taxa **Riparian thickets** Small Trees: *Acacia karroo* (d), *Euclea pseudebenus* (d), *Salix mucronata* subsp. *mucronata* (d), *Schotia afra* var. *angustifolia* (d), *Ziziphus mucronata* (d), *Acacia erioloba*, *Combretum erythrophyllum*, *Ficus cordata*, *Maerua gilgii*, *Prosopis glandulosa* var. *glandulosa*, *Rhus lancea*. Tall Shrubs: *Gymnosporia linearis* (d), *Tamarix usneoides* (d), *Ehretia rigida*, *Euclea undulata*, *Sisyndite spartea*. Low Shrub: *Asparagus laricinus*. Woody Climber: *Asparagus retrofractus*. Succulent Shrub: *Lycium bosciifolium*. Herb: *Chenopodium olukondae*. **Reed beds** Megagraminoid: *Phragmites australis* (d). **Flooded grasslands & herblands** Low Shrubs: *Tetragonia schenckii* (d), *Litogyne gariepina*. Graminoids: *Cynodon dactylon* (d), *Setaria verticillata* (d), *Cenchrus ciliaris*, *Cyperus laevigatus*, *Eragrostis echinochloidea*, *Leucophrys mesocoma*, *Polypogon monspeliensis*, *Stipagrostis namaquensis*. Herbs: *Amaranthus praetermissus*, *Coronopus integrifolius*, *Frankenia pulverulenta*, *Gnaphalium confine, Pseudognaphalium luteo-album*.

Conservation Endangered. Target 31%. About 6% statutorily conserved in the Richtersveld and Augrabies Falls National Parks. Some 50% transformed for agricultural purposes (vegetables and grapes) or alluvial diamond mining. *Prosopis* species, *Nicotiana glauca* and *Argemone ochroleuca* can invade the alluvia in places.

References Acocks (1976), Werger & Coetzee (1977), Werger & Ellenbroek (1978), Werger (1980), Bezuidenhout (1996), Bezuidenhout & Jardine (2001), Jürgens (2004).

AZa 4 Upper Gariep Alluvial Vegetation

Including Riverine Communities (*Diospyros lycioides*) (Werger 1980).

Distribution Free State and Northern Cape Provinces: Broad alluvia of the Orange River, lower Caledon as well as lower stretches of the Vaal, Riet and Modder Rivers as far as Groblershoop. These river stretches are surrounded by vegetation units of broad transitional regions between the dry facies of the Savanna and Grassland and northern regions of the Nama-Karoo Biome. Altitude ranging from 1 000–1 500 m.

Vegetation & Landscape Features Flat alluvial terraces supporting complex of riparian thickets (gallery forests) dominated by native *Acacia karroo* and *Diospyros lycioides*, flooded grasslands, reed beds and ephemeral herblands populating mainly sand banks within the river and on its banks.

Geology, Soil & Hydrology Recent alluvial deposits underlain mostly by Karoo Supergroup sediments and tillites, supporting soils typical of Ia group land types. Subject to flooding, especially in summer.

Climate Bimodal (equinoctial) climate with a major peak in March and with a lesser peak in November–December. The overall MAP is 325 mm (range 230–600 mm for Prieska and Wepener, respectively). MAT for the entire area averages 17°C (range 19.3–15.4°C for Prieska and Aliwal North, respectively). See also climate diagram for AZa 4 Upper Gariep Alluvial Vegetation (Figure 13.2).

Important Taxa **Riparian thickets** Small Trees: *Acacia karroo* (d), *Celtis africana* (d), *Salix mucronata* subsp. *mucronata* (d). Tall Shrubs: *Diospyros lycioides* (d), *Melianthus comosus* (d), *Rhus pyroides*. Low Shrubs: *Asparagus setaceus*, *A. suaveolens*. Woody Climber: *Clematis brachiata*. Succulent Shrubs: *Lycium arenicola*, *L. hirsutum*. Herb: *Rubia cordifolia*. **Flooded grasslands & herblands** Graminoid: *Melica decumbens* (d). Herbs: *Cineraria dregeana*, *C. lobata*.

Conservation Vulnerable. Target 31%. Only about 3% statutorily conserved in Tussen Die Riviere, Gariep Dam and Oviston Nature Reserves. More than 20% transformed for cultivation

P.J. du Preez

Figure 13.26 AZa 4 Upper Gariep Alluvial Vegetation: Riparian thickets with dominant *Acacia karroo* and *Diospyros lycioides* fringing the banks of the Orange River near Colesberg.

(vegetables, grapes) and building of dams. Exotic woody species such as *Salix babylonica*, *Eucalyptus camaldulensis*, *E. sideroxylon*, *Prosopis* and *Populus* species have become common dominants in patches of heavily disturbed alluvial vegetation.

References Werger (1973, 1980), Acocks (1976), Werger & Ellenbroek (1978), Du Preez (1991), Du Preez & Bredenkamp (1991).

AZa 5 Highveld Alluvial Vegetation

Distribution Free State, North-West, Mpumalanga and Gauteng Provinces as well as in Lesotho and Swaziland: Alluvial drainage lines and floodplains along rivers embedded within the Grassland Biome and marginal (eastern) units of the Kalahari (Savanna Biome), such as along upper Riet, Harts, upper Modder, upper Caledon, Vet, Sand, Vals, Wilge, Mooi, middle and upper Vaal Rivers etc. and their numerous tributaries. Altitude ranging from 1 000–1 500 m.

Vegetation & Landscape Features Flat topography supporting riparian thickets mostly dominated by *Acacia karroo*, accompanied by seasonally flooded grasslands and disturbed herblands often dominated by alien plants.

Geology, Soil & Hydrology Deep sandy to clayey (but mostly coarse sand) alluvial soils developed over Quaternary alluvial (fluviatile) sediments. Oakleaf, Dundee, Shortlands, Glenrosa and Mispah soil forms were identified in the Vaal River floodplain (Bezuidenhout 1994). The rivers are perennial, often in flood in summer. Erosion of banks and deposition of new fine soil on alluvium can be of considerable extent. Some smaller anastomosing channels of major rivers can dry out in winter.

Climate Seasonal, mainly summer rainfall. Precipitation in the western part of the highveld is erratic (MAP 300–400 mm), increasing sharply towards the east and north (up to 600 mm in places). The overall MAP is almost 500 mm (range 373 mm at the western distribution limit and 593 mm at the northern distribution limit near Carletonville). Typical continental thermal regime, showing subtropical features is typical of the summer season (daily temperature often surpassing 35°C), while cold-temperate features (such as frequent frost) prevail in winter. See also climate diagram for AZa 5 Highveld Alluvial Vegetation (Figure 13.2).

Important Taxa **Riparian thickets** Small Trees: *Acacia karroo* (d), *Salix mucronata* subsp. *mucronata* (d), *S. mucronata* subsp. *woodii* (d, within subescarpment grasslands of KwaZulu-Natal), *Ziziphus mucronata* (d), *Celtis africana*, *Rhus lancea*. Tall Shrubs: *Gymnosporia buxifolia* (d), *Rhus pyroides* (d), *Diospyros lycioides*, *Ehretia rigida*, *Grewia flava*. Low Shrubs: *Asparagus laricinus* (d), *A. suaveolens* (d). Woody Climber: *Clematis brachiata*. Succulent Shrub: *Lycium hirsutum* (d). Graminoids: *Setaria verticillata* (d), *Panicum maximum*. Herb: *Pollichia campestris*. **Reed beds** Megagraminoid: *Phragmites australis* (d). **Flooded grasslands & herblands** Low Shrubs: *Gomphocarpus fruticosus* (d), *Felicia muricata*. Succulent Shrub: *Salsola rabieana*. Graminoids: *Agrostis lachnantha* (d), *Andropogon eucomus* (d), *Chloris virgata* (d), *Cynodon dactylon* (d), *Eragrostis plana* (d), *Hemarthria altissima* (d), *Imperata cylindrica* (d), *Ischaemum fasciculatum* (d), *Miscanthus junceus* (d), *Paspalum distichum* (d), *Andropogon appendiculatus*, *Brachiaria marlothii, Cyperus denudatus*, *C. longus*, *Echinochloa holubii*, *Eragrostis obtusa*, *E. porosa*, *Fimbristylis ferruginea, Panicum coloratum*, *Pycreus mundii*, *Sporobolus africanus*, *S. fimbriatus*, *Themeda triandra*, *Urochloa panicoides*. Herbs: *Persicaria lapathifolia* (d), *Alternanthera sessilis*, *Barleria macrostegia*, *Corchorus asplenifolius*, *Equisetum ramosissimum*, *Galium capense*, *Hibiscus pusillus*, *Lobelia angolensis, Nidorella resedifolia*, *Persicaria amphibia, P. hystricula*, *Pseudognaphalium oligandrum*, *Pulicaria scabra, Rorippa fluviatilis* var. *fluviatilis*, *Senecio inornatus*, *Stachys hyssopoides*, *Vahlia capensis*. Geophytic Herbs: *Crinum bulbispermum*, *Haplocarpha lyrata*. **Open water** Aquatic Herb: *Myriophyllum spicatum*.

Conservation Least threatened. Target 31%. Nearly 10% statutorily conserved in the Barberspan (a Ramsar site), Bloemhof Dam, Christiana, Faan Meintjes, Sandveld, Schoonspruit, Soetdoring and Wolwespruit Nature Reserves. More than a quarter has been transformed for cultivation and by building of dams (Bloemhof, Erfenis, Krugersdrif, Mockes and Vaalharts Dams). The highveld alluvia are prone to invasion by a number of weeds, obviously encouraged by the high nutrient status of soils and ample water supply. Woody plants such as *Salix babylonica*, *Schinus molle*, *Melia azedarach*, *Celtis sinensis*, *Morus alba*, *Populus* x *canescens*, *Nicotiana glauca* and *N. longiflora* and forbs such as *Argemone ochroleuca*, *Chenopodium strictum*, *Conyza canadensis*, *Datura stramonium*, *Melilotus alba*, *Oenothera indecora*, *Paspalum dilatatum*, *P. urvillei*, *Pennisetum clandestinum*, *Tagetes minuta*, *Verbena bonariensis*, *Xanthium strumarium* agg. and *Zinnia peruviana* (see Cilliers et al. 1998, Malan et al. 2001a, b, L. Mucina, unpublished data) often dominate either the riverine thickets or grasslands or form ruderal communities in disturbed habitats. The undergrowth of the alluvial riparian thickets and the accompanying grasslands suffer from heavy overgrazing in many places.

Remark Many patches of this vegetation escaped our mapping efforts due to a lack of proper geographical coverage.

References Acocks (1976), Roussouw (1983), Müller (1986), Bezuidenhout (1988, 1994), Bredenkamp et al. (1989), Bredenkamp & Bezuidenhout (1990), Du Preez & Venter (1990), Kooij et al. (1990a, b), Du Preez (1991), Du Preez & Bredenkamp (1991), Eckhardt et al. (1993b, 1996), Bezuidenhout et al. (1994), Bredenkamp et al. (1994), Hoare (1997), Cilliers et al. (1998), Eckhardt (1998), Malan (1998), Boucher & Tlale (1999a, b), Hoare & Bredenkamp (1999), Myburgh (2000, 2001), Van Wyk et al. (2000), Dingaan et al. (2001), Malan et al. (2001a, b), Myburgh & Bredenkamp (2004), http://www.ngo.grida.no/soesa/nsoer/resource/wetland/sa_ramsar.htm.

AZa 6 Albany Alluvial Vegetation

Including Stream-bank Bush (Story 1952). Riverine Bush (Martin & Noel 1960). Baviaans Doringveld, Gamtoos Doringveld & Sundays Doringveld (Vlok & Euston-Brown 2002, Vlok et al. 2003).

Distribution Eastern Cape Province: Between East London and Cape St Francis on wide floodplains (usually close to the coast where the topography becomes flatter) of the large rivers such as the Sundays, Zwartkops, Coega, Gamtoos, Baviaanskloof, Great Fish River etc. This alluvial unit is embedded within the Albany Thicket Biome. Altitude ranging from 20–1 000 m.

Vegetation & Landscape Features Two major types of vegetation pattern are observed in these zones, namely riverine thicket and thornveld (*Acacia natalitia*). The riverine thicket tends to occur in the narrow floodplain zones in regions close to the coast or further inland, whereas the thornveld occurs on the wide floodplains further inland.

Geology, Soil & Hydrology Underlain by Jurassic-Cretaceous sediments of the Uitenhage Group. The alluvial zones (recent alluvial deposits of various textures, but usually with high clay content) can become flooded following the west-east passage of frontal systems in autumn and winter or during intensive local storms in summer. Ia land type.

Climate Characterised by undifferentiated, year-round precipitation regime, with only two slight peaks in March and November.

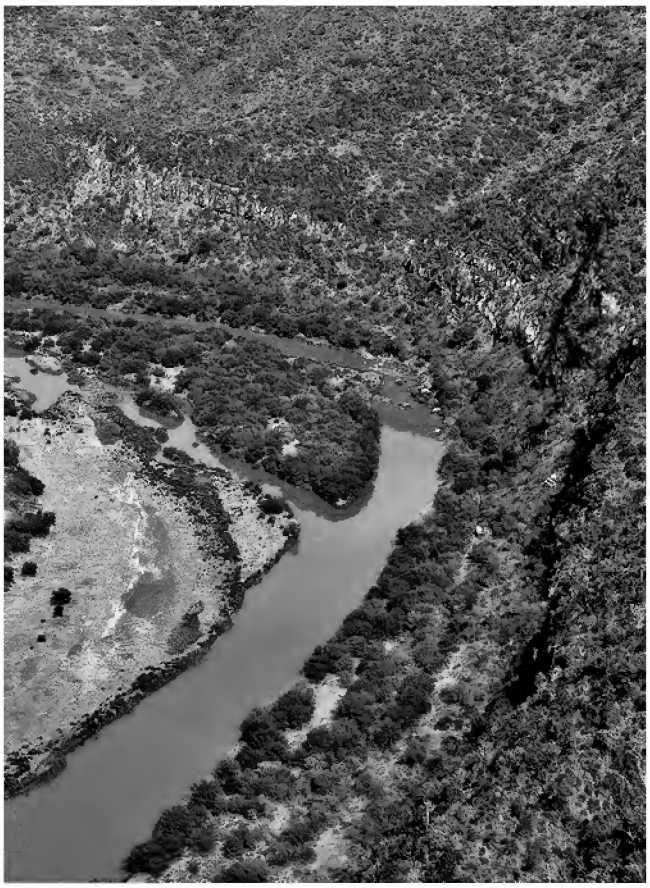


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Figure 13.27 AZa 6 Albany Alluvial Vegetation: *Acacia natalitia* thickets fringing the Great Fish River in the former Double Drift Nature Reserve near Fort Beaufort (Eastern Cape).

The overall MAP is 350 mm (range 300–717 mm). Warm-temperate climate (overall MAT 18°C; range 15.7–18.3°C). The river valleys are often hotter than the surrounding landscape (due to exposed steep slopes), whereas riverine zones closer to the coast enjoy an ameliorated climate due to its proximity to the sea. See also climate diagram for AZa 6 Albany Alluvial Vegetation (Figure 13.2).

Important Taxa ([B]Brackish habitats): **Riparian thickets** Small Trees: *Acacia natalitia* (d), *Salix mucronata* subsp. *mucronata* (d), *Schotia afra* var. *afra* (d), *Acacia caffra*, *Rhus longispina*. Succulent Trees: *Aloe africana*, *A. ferox*. Tall Shrubs: *Azima tetracantha*, *Cadaba aphylla*. Low Shrubs: *Pentzia incana* (d), *Asparagus striatus*, *A. suaveolens*, *Carissa haematocarpa*. Succulent Shrubs: *Amphiglossa callunoides*, *Lycium cinereum*. Graminoids: *Sporobolus nitens* (d), *Digitaria eriantha*, *Eragrostis curvula*, *E. obtusa*. **Reed beds** Megagraminoids: *Cyperus papyrus* (d), *Phragmites australis* (d). **Flooded grasslands & herblands** Succulent Shrubs: *Cotyledon campanulata*[B], *Glottiphyllum longum*[B], *Malephora lutea*[B], *M. uitenhagensis*[B]. Semiparasitic Shrub: *Thesium junceum*[B]. Succulent Herbs: *Haworthia sordida* var. *sordida*[B], *Orbea pulchella*[B]. Herb: *Rorippa fluviatilis* var. *fluviatilis*. Graminoid: *Cynodon dactylon*[B] (d).

Conservation Endangered. Target 31%. Only about 6% statutorily conserved in the Greater Addo Elephant National Park, Baviaanskloof Wilderness Area, Loerie Dam, Springs, Swartkops Valley and Yellowwoods Nature Reserves and the Double Drift Reserve Complex. About 2% enjoys protection in eight private conservation areas. More than half of the area has been transformed for cultivation, urban development, road building and plantations. Alien invaders include *Acacia saligna*, *Nerium oleander* and *Eucalyptus* species.

Remarks Vlok & Euston-Brown (2002) consider this vegetation as important temporary habitats and migration corridors for larger herbivores such as elephant (in the past), rhinoceros, eland and kudu.

References Story (1952), Martin & Noel (1960), Jessop & Jacot Guillarmod (1969), Jacot Guillarmod (1973), Acocks (1976), Cowling & McKenzie (1979), Vlok & Euston-Brown (2002), Vlok et al. (2003).

AZa 7 Subtropical Alluvial Vegetation

Including Riverine Bush (Comins 1962). *Salvadora angustifolia* Floodplains (Gertenbach 1983).

Distribution Limpopo, Mpumalanga and KwaZulu-Natal Provinces and in Swaziland: Broad river alluvia and around some river-fed pans in the subtropical regions of eastern South Africa, in particular in the Lowveld, Central Bushveld and in northern KwaZulu-Natal. The most important alluvia include the Limpopo, Luvubu, Olifants, Sabie, Crocodile, Phongolo, Usutu and Mkuze Rivers. This unit is fully embedded within the Savanna Biome. Altitude ranging from 0–1 000 m.

Vegetation & Landscape Features Flat alluvial riverine terraces supporting an intricate complex of macrophytic vegetation (channel of flowing rivers and river-fed pans), marginal reed belts (in sheltered oxbows and along very slow-flowing water courses) as well as extensive flooded grasslands, ephemeral herblands and riverine thickets.

Geology, Soil & Hydrology Recent alluvial deposits with deep fine-structured sandy to loamy soils (Dundee, Estcourt, Valsrivier, Sterkspruit, Oakleaf forms), waterlogged as it is often exposed to floods (especially during the rainy summer season). Salt often

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Figure 13.28 AZa 7 Subtropical Alluvial Vegetation: Complex of reed beds (*Phragmites mauritanicus*) and alluvial shrublands along the White Mfolozi River (Hluhluwe-iMfolozi Park, KwaZulu-Natal).

accumulates in the alluvial soils (due to strong evaporation). Ia land type.

Climate Subtropical, seasonal summer-rainfall climate with broad range of temperature (19.3°C in western Central Bushveld and 22.0°C in Mopane) and precipitation (MAP 311–672 mm for Limpopo Valley and Maputaland, respectively) due to large latitudinal and longitudinal ranges. See also climate diagram for AZa 7 Subtropical Alluvial Vegetation (Figure 13.2).

Important Taxa **Riparian thickets** Small Trees: *Acacia natalitia* (d), *A. robusta* (d), *Boscia foetida* subsp. *rehmanniana* (d), *Combretum erythrophyllum* (d), *Phoenix reclinata* (d), *Salix mucronata* subsp. *woodii* (d), *Ziziphus mucronata* (d), *Acacia luederitzii*, *A. nebrownii*, *A. nigrescens*, *A. tortilis*, *A. xanthophloea*, *Colophospermum mopane*, *Combretum hereroense*, *Philenoptera violacea*, *Pseudoscolopia polyantha* (Pondoland, sharing with Capensis). Tall Shrubs: *Salvadora angustifolia* (d), *Commiphora glandulosa*, *C. pyracanthoides*, *Euclea divinorum*, *Grewia bicolor*, *Gymnosporia senegalensis*. Low Shrubs: *Justicia flava*, *Ocimum canum*. Graminoids: *Eragrostis trichophora* (d), *Panicum maximum* (d), *Setaria incrassata* (d), *Sporobolus ioclados* (d), *Chloris virgata*, *Dactyloctenium aegyptium*, *Enneapogon cenchroides*, *Urochloa mosambicensis*. Herbs: *Commelina benghalensis* (d), *Abutilon austro-africanum*, *Acalypha indica*, *Achyranthes aspera*, *Boerhavia erecta*, *Commicarpus fallacissimus*, *Cucumis zeyheri*, *Heliotropium ovalifolium*, *Lobelia angolensis, Oxygonum sinuatum*, *Pupalia lappacea*, *Ruellia patula*. Geophytic Herb: *Crinum moorei*. Succulent Herb: *Portulaca quadrifida*. **Reed beds** Megagraminoids: *Phragmites australis* (d), *P. mauritianus* (d), *Prionium serratum* (only along few rapids in Pondoland). **Flooded grasslands & herblands** Megagraminoid: *Cyperus immensus*. Graminoids: *Cynodon dactylon* (d), *Cyperus articulatus* (d), *Echinochloa pyramidalis* (d), *Urochloa mosambicensis* (d), *Bolboschoenus glaucus, Chloris mossambicensis*, *C. virgata*, *Cyperus corymbosus*, *C. difformis*, *C. distans*, *C. fastigiatus*, *C. sexangularis*, *Dactyloctenium aegyptium*, *Hemarthria altissima*, *Ischaemum afrum*, *Paspalidium obtusifolium*, *Setaria sphacelata*, *Sporobolus consimilis*, *S. fimbriatus*. Herbs: *Alternanthera sessilis*, *Amaranthus praetermissus*, *Grammatotheca bergiana* (Pondoland), *Marsilea ephippiocarpa, Scutellaria racemosa*. Geophytic Herb: *Trachyandra saltii*. Aquatic Herbs: *Ceratophyllum muricatum*, *Ottelia exserta*.

Endemic Taxon **Flooded grasslands & herblands** Herb: *Crotalaria mollii*.

Conservation Target 31%. Large patches are statutorily conserved in the Kruger and Mapungubwe National Parks, Vemre and D'nyala Nature Reserves, Ndumo Game Reserve and Greater St Lucia Wetland Park (Mkhuze Game Reserve) as well as in a number of private reserves fringing the western borders of the Kruger National Park and the Limpopo River. The Ndumo Game Reserve and Greater St Lucia Wetland Park are Ramsar sites. Much of the area has been transformed for cultivation, urban development and road building. Alien woody species commonly occurring in this vegetation types include *Melia azedarach*, *Chromolaena discolor* and the like.

Remark 1 The vegetation of the Lowveld alluvia is found in a complex of Subtropical Riverine Forests (gallery forests), and both are usually embedded within various bushveld types of the Savanna Biome. The major distinction between this type of alluvial vegetation and other alluvia is the presence and importance of subtropical and tropical floristic elements and the pronouncedly subtropical climate. One of the best researched subtropical alluvial systems in South Africa is the Nylsvlei east of the Modimolle–Mookgophong line, especially in the Nylsvlei Nature Reserve (Coetzee et al. 1976).

Remark 2 The current mapping coverage of Subtropical Alluvial Vegetation reflects our current poor knowledge and the lack of data from all around the Central Bushveld as well as Lowveld regions.

References Comins (1962), Edwards (1967), Musil (1972), Musil et al. (1973), Theron (1973), Acocks (1976), Coetzee et al. (1976), De Moor et al. (1977), Noble & Hemens (1978), Furness & Breen (1980), Heeg et al. (1980), Rogers (1980, 1984), Furness (1981), Gertenbach (1983), Goodman (1987a, b), Begg & Carser (1988, 1989), Breen et al. (1993), Brown & Bredenkamp (1994), Bredenkamp & Deutschländer (1995), Brown et al. (1995, 1996, 1997), Breebaart & Deutschländer (1997), Kotschy et al. (2000), Barnes et al. (2002), Götze (2002), Götze et al. (2003), O'Keeffe & Rogers (2003).

Inland Saline Vegetation

AZi 1 Namaqualand Riviere

Distribution Northern and Western Cape Provinces: Along dry riverbeds throughout Namaqualand, but especially the Buffels, Bitter, Spoeg, Groen, Sout, Doring Rivers and lower reaches of the Olifants River. Within this unit we also classify alluvia of intermittent rivers of the Hantam region. Altitude ranging from 0–800 m.

Vegetation & Landscape Features Complex of alluvial shrubland (*Suaeda fruticosa*, *Zygophyllum morgsana*, *Ballota africana* and *Didelta spinosa*) and patches of tussock graminoids occupying riverbeds and banks of intermittent rivers. In places low thickets of *Acacia karroo* and *Tamarix usneoides* can be encountered.

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Figure 13.29 AZi 1 Namaqualand Riviere: Broad sandy-loamy alluvium of the Varsch River northwest of Vanrhynsdorp, with *Acacia karroo* (yellow-flowered shrub) and species of *Salsola* and *Galenia* (low greyish shrubs).

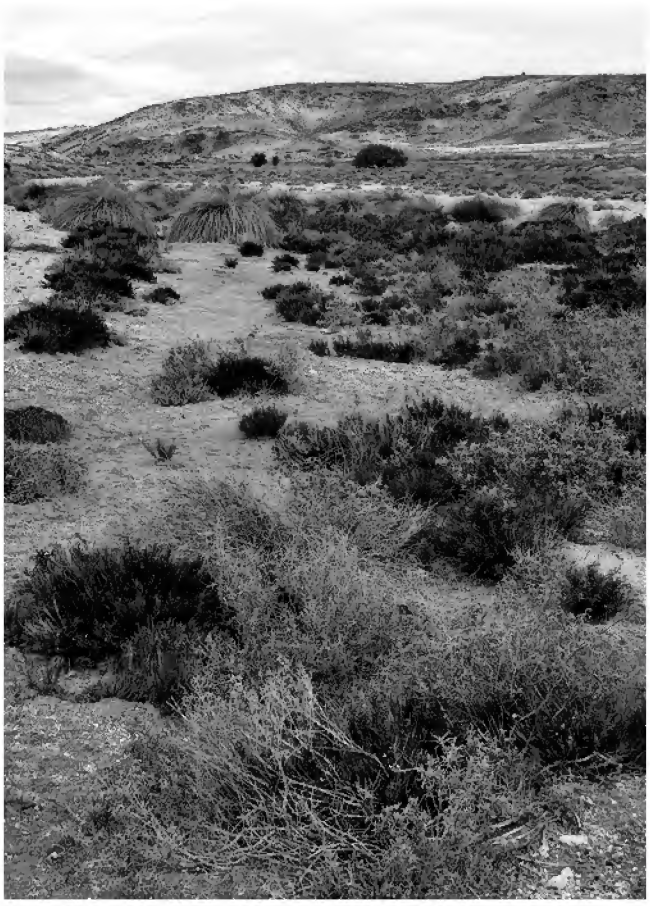

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Figure 13.30 AZi 1 Namaqualand Riviere: Salty bottom of intermittent semidesert river on the Knersvlakte with *Sarcocornia terminalis* (endemic Chenopodiaceae), *Galenia africana* and salt-loving *Limonium dregeanum* (Plumbaginaceae, dark green tussocks).

Geology, Soil & Hydrology Alluvial sandy soils on Quaternary fluviatile sediments that overlie Namibian-age sediments and Mokolian gneisses. Seasonally wet (late winter). The riverbed sometimes carries torrential flood waters. In summer, patches of crystallised salt film may cover the soil surface in slight, clayey depressions.

Climate Arid, seasonal climate with MAP around 150 mm (with 100 mm on the coast and 250 mm on the Hantam Plateau). Most of the erratic rainfall occurs between June and August. Hot summers (marked by extremely high evapotranspiration) and cool winters, with fairly frequent frost. MAT 18.1°C (range 15.7°C for Hantam Plateau and 18.5°C for Knersvlakte). See also climate diagram for AZi 1 Namaqualand Riviere (Figure 13.2).

Important Taxa **Riparian thickets** Small Tree: *Acacia karroo* (d). Tall Shrubs: *Melianthus pectinatus*, *Rhus burchellii*, *Tamarix usneoides*. Low Shrub: *Ballota africana* (d). Semiparasitic Epiphytic Shrub: *Viscum capense*. **Dry river bottoms** Tall Shrub: *Lebeckia sericea*. Low Shrubs: *Galenia africana* (d), *Gomphocarpus fruticosus* (d), *Hermannia disermifolia*, *Jamesbrittenia fruticosa*, *Salvia dentata*. Succulent Shrubs: *Suaeda fruticosa* (d), *Zygophyllum morgsana* (d), *Atriplex cinerea* subsp. *bolusii*, *Didelta carnosa* var. *carnosa*, *Lycium horridum*, *Salsola tuberculata*, *Tetragonia fruticosa*, *T. pillansii*, *Zygophyllum retrofractum*. Herbaceous Climber: *Didymodoxa capensis*. Graminoids: *Cynodon dactylon* (d), *Odyssea paucinervis* (d), *Cyperus marginatus*, *Diplachne fusca*, *Ehrharta longiflora*, *Isolepis antarctica*, *Scirpus nodosus*. Herbs: *Limonium dregeanum* (d), *Arctotheca calendula*, *Cotula coronopifolia*, *Galium tomentosum*. Geophytic Herb: *Crinum variabile*. Succulent Herbs: *Conicosia elongata*, *Mesembryanthemum guerichianum*.

Endemic Taxon **Dry river bottoms** Succulent Shrub: *Sarcocornia terminalis* (d).

Conservation Least threatened. Target 24%. Only very small portion statutorily protected in nature reserves (Lutzville). Almost 20% transformed for cultivation (vineyards along the entire lower reaches of the Olifants River) or by building of dams (Driekoppies Dam). Exotic shrubs *Nicotiana glauca* and *Prosopis* species are often found in riverbeds. The latter is probably the most important woody invader species found in Namaqualand. In some years invasive indigenous *Gomphocarpus fruticosus* may appear in abundance in the alluvia, while in other years it would disappear completely. Another invasive indigenous species is *Galenia africana* which can be dominant along some of the water courses, especially in the south.

Reference Boucher (2003).

AZi 2 Namaqualand Salt Pans

Distribution Northern and Western Cape Provinces: Smaller and larger areas along the coastal plains of Namaqualand, including Sonnekwa, Hondevlei (both southeast of Kleinzee), Bloupan, Dryerspan, Karaspan (north of Kleinzee) and Soutpan (southeast of Port Nolloth). The cut-off supratidal terraces of the Olifants River mouth qualify as salt pans as well. Altitude ranging from 0–250 m.

Vegetation & Landscape Features Flat surfaces of depressions, mostly without vegetation and only occasionally covered with sparse, highly salt-tolerant succulent shrubs (*Salsola*, *Malephora*). The highest vegetation cover has been found in the salt pan at the Olifants River mouth, where the succulent shrubs *Salsola*, *Psilocaulon* and *Sarcocornia* are dominant.

Geology, Soil & Hydrology Large depressions (pans) of marine origin (remnants of former larger marine transgression-forming coastal lagoons) with white to grey silt and clay soils, seasonally moist. These pans are formed on the Cenozoic alluvium, sand and calcrete that were deposited over Mokolian-age schists and gneisses as well as metavolcanics and metasediments of Namibian age. Namaqualand salt pans are nearly permanently dry (only seldom intermittent pools of standing water are found in the lowest depressions) and especially in the Kleinzee area they disappear and are buried under layers of wind-borne sand.

Climate Arid, erratic seasonal rainfall of which most falls between May and August. Overall MAP 100 mm, ranging from 45 mm at Alexander Bay to 126 mm on the Knersvlakte below the Bokkeveld Escarpment. Along the Richtersveld coast the lack of rainfall is partly compensated by more frequent coastal winter fog. Hot summers (accompanied by high evapotranspiration rates) alternate with cool winters. MAT ranging from 17.6°C, with narrow range of 17.3–18.6°C. See also climate diagram for AZi 2 Namaqualand Salt Pans (Figure 13.2).

Important Taxa Succulent Shrubs: *Salsola aphylla* (d), *Sarcocornia mossiana* agg. (d), *Atriplex cinerea* subsp. *bolusii*. Succulent Herbs: *Mesembryanthemum guerichianum*, *Salicornia meyeriana*. Graminoids: *Juncus rigidus* (d), *Sporobolus virginicus*.

Biogeographically Important Taxa ([NQ]Namaqualand endemic, [G]Gariep endemic, [W]West Coast endemic): Low Shrub: *Frankenia pomonensis*[G]. Succulent Shrub: *Lycium tetrandrum*[W]. Herbs: *Malephora purpureo-crocea*[NQ] (d), *Limonium equi-*

setinum[W]. Succulent Herb: *Psilocaulon dinteri*[W]. Graminoid: *Schoenoplectus scirpoides*.

Conservation Least threatened. Target 24%. None conserved in statutory conservation areas. Only small portion transformed (road building).

Remarks The Namaqualand pans are superficially (physiognomy, ecology) very similar to those of Bushmanland such as Verneukpan and other 'vloere', but they differ in terms of origin (marine versus fluviatile) and also in constituent flora. The salt pan at the Olifants River mouth is an example of an 'inland' pan in *stadio nascendi*—some supratidal terraces of the original estuarine salt marsh are becoming isolated from any influence of the tidal regime, forming an isolated saline system resulting in a pan.

References Bornman (2002), Bornman et al. (2002, 2004).

AZi 3 Southern Kalahari Mekgacha

Distribution Northern Cape and North-West Provinces: Valleys (including beds and adjacent slopes) of the intermittent rivers draining the dry savanna south of the Bakalahari Schwelle (broad interfluve at 1 000–1 100 m altitude) in the South African part of the Kalahari region. The major mekgacha of the region include the Nossob, Auob, Molopo and Kuruman Rivers. A more extensive (endorheic) system of mekgacha is found north of the Bakalahari Schwelle in central Botswana. Altitude ranging from 850 m to mainly 1 100 m, with a few occurrences as high as 1 500 m.

Vegetation & Landscape Features Sparse, patchy grasslands, sedgelands and low herblands dominated by C_4 grasses (*Panicum*, *Eragrostis*, *Enneapogon*, *Tragus*, *Chloris*, *Cenchrus*) on the bottom of (mostly) dry riverbeds. Low shrublands in places with patches of taller shrubland (with *Schotia afra*) on the banks of the rivers. Relatively tall *Acacia erioloba* trees can form a dominant belt along some of the rivers, for example the middle and lower reaches of the Kuruman River. In some other rivers the taller trees are scattered.

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Figure 13.31 AZi 3 Southern Kalahari Mekgacha: Dry Nossob River in the Kgalagadi Transfrontier Park against the backdrop of sparsely vegetated dunes in neighbouring Botswana. For springbok (*Antidorcas marsupialis*) and other hoofed as well as carnivorous wildlife the open landscape of the intermittent rivers is a favourite grazing, resting and hunting ground.

Geology, Soil & Hydrology The river channels are embedded within prevalently sandy Kalahari sediments that cover the Precambrian metamorphic crust of the area. The substrate of the dry riverbeds are silty, sandy and rocky, poorly drained and rich in nutrients though the ionic composition of the soils in particular rivers show considerable differences. The banks of the dry rivers can cut deep into duricrust (calcrete or silcrete and various transitions between these end-members, and in places also ferricretes), sometimes vertical bluffs (steep cliffs) of a few metres high may develop (Werger 1978, Thomas & Shaw 1991). The mekgacha may stay without any water for a very long time and floods (sometimes of considerable magnitude) occur only in response to dramatic short-term precipitation events, for example the Nossob was in flood in 1806, 1963 and 1987 and the Auob was in flood in 1973, 1974 and 2000 (Thomas & Shaw 1991; H. Bezuidenhout, personal communication). Some of the rivers such as the Kuruman must experience effective subsurface flow of water judging from the near-continuous belt of trees.

Climate Subarid region with seasonal, summer-rainfall regime with a slight shift of the major peak towards late summer (February–March). Overall MAP 240 mm (ranging from 180 mm at southwestern boundary to as much as 420 mm further north). High thermic continentality is obvious from the extreme differences between the mean daily maximum and minimum temperatures in January and July: 34°C and 1°C, respectively, great daily temperature differences (sometimes reaching amplitude between 25°C and 30°C, especially in transitional climatic periods) as well as the fairly frequent occurrence of frost. The overall MAT of 19°C (range 17.5–19.1°C) is indicative of a subtropical climate, classified in the Köppen's system as BWKw' in its southernmost regions and as BWhw further north (Coetzee & Werger 1975, Schultze & McGee 1978, Werger 1978). See also climate diagram for AZi 3 Southern Kalahari Mekgacha (Figure 13.2).

Important Taxa **Dry river bottoms** Tall Shrubs: *Lebeckia linearifolia* (d), *Sisyndite spartea* (d), *Deverra denudata* subsp. *aphylla*. Herbs: *Amaranthus dinteri* subsp. *dinteri*, *A. praetermissus*, *A. schinzianus*, *Boerhavia repens*, *Chamaesyce inaequilatera*, *Cucumis africanus*, *Geigeria ornativa*, *G. pectidea*, *Heliotropium lineare*, *Indigofera alternans*, *I. argyroides*, *Kohautia cynanchica*, *Lotononis platycarpa*, *Osteospermum muricatum*, *Platycarpha carlinoides*, *Radyera urens*, *Stachys spathulata*, *Tribulus terrestris*. Succulent Herb: *Zygophyllum simplex* (d). Graminoids: *Cenchrus ciliaris* (d), *Chloris virgata* (d), *Enneapogon desvauxii* (d), *Eragrostis annulata* (d), *E. bicolor* (d), *Odyssea paucinervis* (d), *Panicum coloratum* (d), *Eragrostis porosa*, *Panicum impeditum*, *Sporobolus nervosus*. **Rocky slopes of river canals** Tall Tree: *Acacia erioloba* (d). Low Shrubs: *Aptosimum lineare*, *Pechuel-Loeschea leubnitziae*. Graminoids: *Setaria verticillata* (d), *Enneapogon scaber*, *Oropetium capense*, *Stipagrostis uniplumis*, *Tragus racemosus*. Herb: *Dicoma capensis*.

Conservation Least threatened. Target 24%. Already 18% statutorily conserved in the Kgalagadi Transfrontier Park and Molopo Nature Reserve. About 2% has been transformed by road building. The

mekgacha are under strong utilisation pressure, both from wildlife (to graze and for salt licks) and domestic animals (grazing, browsing and animal penning). Alien woody *Prosopis* species occur as invasive plants in places.

Remark 1 The term 'mekgacha' (singular 'mokgacha') is of Setswana origin and means 'dry (river) valley'. Mekgacha are considered to be remnants of an ancient extensive riverine system of the 'Kalahari River', which drained the Kalahari Basin and used the current lower Orange River channel from Kakamas downstream. In the early Tertiary, the Kalahari River captured the upper parts of the Karoo River (draining the inland plateau of southern Africa into the southern Atlantic Ocean at the current mouth of the Olifants River on the West Coast and with the present offshore submarine Cape Canyon as outlet) as a result of accelerated uplift of the southern and eastern subcontinental margins ca. 100 to 80 mya (De Wit 1999, Goudie 2005). The flow of the Kalahari River system was interrupted by the dry periods of the Eocene-Miocene transition and further decimated during Plio-Pleistocene dry periods.

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Figure 13.32 AZi 4 Southern Kalahari Salt Pans: A salt pan in the northern Kgalagadi Transfrontier Park near a dry riverbed of the Nossob, surrounded by shrubby savanna with *Rhigozum trichotomum* (Bignoniaceae) and *Schmidtia kalahariensis* (Poaceae) dominant.

Remark 2 The Southern Kalahari Mekgacha differ from the Bushmanland Vloere and Southern Karoo Riviere in climatic, geological (origin) and floristic terms. The Bushmanland pans (vloere) are distinguished by an increased occurrence of shrubby elements (especially *Salsola* and similar karoo dwarf shrubs), while the Southern Karoo Riviere have well-developed tall-shrub structures fringing the riverbeds but lack the *Acacia erioloba* of the Mekgacha.

Remark 3 Some of the longer rivers in the region, especially the Molopo, have a generally progressive reduction in larger woody plant cover in a downstream direction due to reduced penetration of water flow with increasing distance into the more arid regions.

References Leistner (1967), Leistner & Werger (1973), Werger & Leistner (1975), Werger & Coetzee (1977), Noble & Hemens (1978), Werger (1978), Thomas & Shaw (1991), De Wit (1999), Smit (2000), Malan (2003), Goudie (2005).

AZi 4 Southern Kalahari Salt Pans

Distribution Northern Cape and North-West Provinces and neighbouring Kalahari regions of Botswana and Namibia: System of endorheic, closed depressions (pans) in the southern Kalahari as defined by Thomas & Shaw (1991) south of the Bakalahari Schwelle. The largest concentrations of such pans in South Africa are found near Groot-Mier in western Gordonia. Altitude ranging from 800–1 500 m.

Vegetation & Landscape Features Low grasslands on pan bottoms (these often devoid of vegetation) often dominated by *Sporobolus* species, with a mixture of dwarf shrubs. The low shrubland dominated by *Lycium* and/or *Rhigozum* usually forms the outer belt in the salt-pan zonation systems.

Geology, Soil & Hydrology Most of the pans formed on the sandy sediments of the Cenozoic Kalahari Group; in the southeast some formed on the dolomites of the Campbell Group (Vaalian-age Griqualand West Supergroup) and in the west some formed on diamictites of the Dwyka Group (Karoo Supergroup). Extensive pan-like areas occur locally in slightly higher-lying portions of dry riverbeds (mekgacha), where they are isolated from the river course by a raised, compact calcareous sand formation—the pan-like alluvium consists of sandy loam and a fairly high content of calcium and phosphate (Leistner & Werger 1973, Werger 1978). The pan soils consist of white (washed) sand in shallow pans ('sand pans'), rocky soils on calcrete outcrops and most typically of clays and sandy clays very rich in Na, K, Mg and are characterised by high a pH, reaching values of 9. The pan bottoms are exposed for most of the year and carry shallow pools for a short time only after very good rains (March–April).

Climate For the climate account of this unit see AZi 3 Southern Kalahari Mekgacha, sharing basically the same region in South Africa. See also climate diagram for AZi 4 Southern Kalahari Salt Pans (Figure 13.2).

Important Taxa Succulent Shrubs: *Zygophyllum tenue* (d), *Salsola scopiformis*. Herbs: *Hirpicium gazanioides*, *Tribulus terrestris*. Succulent Herb: *Trianthema triquetra* subsp. *parvifolia*. Graminoids: *Enneapogon desvauxii* (d), *Eragrostis truncata* (d), *Sporobolus coromandelianus* (d), *S. rangei* (d), *Panicum impeditum*.

Conservation Least threatened. Target 24%. About 8% statutorily conserved in the Kgalagadi Transfrontier Park. The vegetation of the pans is subject to natural degradation/regeneration cycles controlled by concentration of grazing animals (antelopes in particular).

References Leistner (1967), Leistner & Werger (1973), Werger & Leistner (1975), Werger & Coetzee (1977), Noble & Hemens (1978), Werger (1978), Lancaster (1986), Skarpe (1986), Thomas & Shaw (1991), Bezuidenhout (1995), Smit (2000).

AZi 5 Bushmanland Vloere

Distribution Northern Cape Province: Vloere (salt pans) of the central Bushmanland Basin as well as the broad riverbeds of the intermittent Sak River (functioning as temporary connection between some of the pans) as well as its numerous ancient (today dysfunctional) tributaries. The patches of this vegetation unit are embedded especially within NKb 6 Bushmanland Basin

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Figure 13.33 AZi 5 Bushmanland Vloere: Shrubland with dominant *Rhigozum trichotomum* (Bignoniaceae) in a 'vloer' near Brandvlei in central Bushmanland (Northern Cape). The yellow-flowered plant is the annual *Gazania lichtensteinii* (Asteraceae).

Shrubland and NKb 3 Bushmanland Arid Grassland and to a lesser extent also within NKb 4, NKu 1, NKu 2 as well as marginal Succulent Karoo units summarised within the bioregion of Trans-Escarpment Succulent Karoo. Altitude 850–1 450 m.

Vegetation & Landscape Features Flat and very even surfaces of pans and broad bottoms of intermittent rivers. The centre of a pan (or the river drainage channel itself) is usually devoid of vegetation; loosely patterned scrub dominated by *Rhigozum trichotomum* and various species of *Salsola* and *Lycium*, with a mixture of nonsucculent dwarf shrubs of Nama-Karoo relationship. In places loose thickets of *Parkinsonia africana*, *Lebeckia linearifolia* and *Acacia karroo* can be found.

Geology, Soil & Hydrology Endorheic pans and alluvia of associated intermittent rivers filled with silty and clayey alluvial deposits with a high content of concentrated salt (sodic soils), supported by Ecca Group shales and Dwyka diamictites (Karoo Supergroup). Watkeys (1999) found that in the pan of Brandvlei, the orthic A horizon is underlain by a soft carbonate subsoil and the soils of the alluvial terraces of the Sak River are deep (more than 1 000 mm), stratified and weakly structured and calcareous. Ia land type. Erosion in some places can be considerable, especially after unpredictable heavy thunderstorms leading to sudden swelling of the Sak River. The pans can be filled in wet summers and in autumn.

Climate Arid, seasonal climate with bimodal (equinoctial) precipitation regime—two peaks, one in March and another in November. Overall MAP 141 mm (range 91 mm in western Bushmanland to 306 mm at northern edges of the Roggeveld). Overall MAT 16.8°C (range 17.4°C in northern Bushmanland to 14.5°C on northern edge of the Roggeveld). The region where the Bushmanland Vloere occur, is known for thermic extremes, both long-term (mean daily temperature in January approaching 32°C and in July only several degrees above zero) and short-term (daily temperature amplitude around 25°C). Frequent occurrence of frost is also indicative of the high thermic continentality of the region. See also climate diagram for AZi 5 Bushmanland Vloere (Figure 13.2).

Important Taxa Tall Shrubs: *Parkinsonia africana*, *Xerocladia viridiramis*. Low Shrubs: *Rhigozum trichotomum* (d), *Aizoon schellenbergii*, *Asparagus glaucus*, *Eriocephalus decussatus*, *E. spinescens*, *Pegolettia retrofracta*. Succulent Shrubs: *Salsola aphylla* (d), *S. glabrescens* (d), *S. rabieana* (d), *Lycium pumilum*, *Salsola gemmifera*. Herbs: *Amaranthus dinteri* subsp. *dinteri*, *Lotononis minima*. Geophytic Herb: *Crinum variabile*. Graminoids: *Stipagrostis ciliata* (d), *S. obtusa* (d), *Sporobolus nervosus*, *Stipagrostis namaquensis*.

Conservation Least threatened. Target 24%. None conserved in statutory conservation areas. About 2% transformed for cultivation or building of dams (Vanwyksvlei Dam). Alien *Prosopis* occurs as scattered in some vloere and dry riverbeds. Several of the pans are mined for salt production.

Remark 1 We have refrained from distinguishing pans and the channels of intermittent rivers (unlike in Namaqualand, Kalahari and Highveld regions) as different major habitat complexes, hence different vegetation units deserving independent status. The pans (vloere) and the intermittent rivers of Bushmanland are closely related in terms of origin, geology and the floristic composition of the vegetation they support and they merge into each other at many localities, making the separation virtually impossible. The extensive pan and river system of Bushmanland is a remnant of the ancient Karoo River and later Palaeo-Orange River which have been draining the centre of the region since the Late Cretaceous (for development of these riverine systems see Dingle & Hendey 1984, De Wit 1999 and Goudie 2005). An important role in (trans)formation of the Bushmanland riverine system was played by the Koa River, which drained the area (then covered by dense tropical forest) from Miocene to Late Quaternary (Pleistocene). The Koa River left its traces through a series of pans spanning Commisioner's Pan located west of Brandvlei and Bosluis se Pan found south of Aggeneys as well as through a broad valley filled with deep red sands in the present-day Koa Valley in northern Bushmanland (see also NKb 4 Bushmanland Sandy Grassland).

Remark 2 A reliable floristic characterisation of this unit is not feasible at this stage due to the pending taxonomic revision of the South African representatives of the genus *Salsola*, one of the most important generic components of vegetation of Bushmanland. The vegetation of the AZi 5 Bushmanland Vloere remains of the least studied in the country.

References Acocks (1953), Noble & Hemens (1978), Le Roux et al. (1985), Day (2005b).

AZi 6 Southern Karoo Riviere

Including Mesic Riparian Bush & Xeric Riparian Bush (Van der Walt 1980). Riparian Thicket (Palmer 1991). *Lycium cinereum-Salsola aphylla* Shrubland & *Acacia karroo-Stipagrostis namaquensis* Riparian Woodland (Rubin & Palmer 1996). *Becium burchellianum-Acacia karroo* Woodland (Brown & Bezuidenhout 2000).

Distribution Western and Eastern Cape Provinces: Alluvia of the Buffels, Bloed, Dwyka, Gamka, Sout, Kariega, and Sundays Rivers and their tributaries), east of Laingsburg as far west as Graaff-Reinet and Jansenville. This vegetation unit is embedded within the Koedoesberge-Moordenaars Karoo, Prince Albert Succulent Karoo, Gamka Karoo, Eastern Lower Karoo, and southern parts of the Eastern Upper Karoo as well as some

parts of the Albany Thicket Biome south of Cradock. Altitude ranging from 250–1 550 m.

Vegetation & Landscape Features Narrow riverine flats supporting a complex of *Acacia karroo* or *Tamarix usneoides* thickets (up to 5 m tall), and fringed by tall *Salsola*-dominated shrubland (up to 1.5 m high), especially on heavier (and salt-laden) soils on very broad alluvia. In sandy drainage lines *Stipagrostis namaquensis* may occasionally also dominate. Mesic thicket forms in the far eastern part of this region (see Van der Walt 1980: Table 4) may also contain *Leucosidea sericea*, *Rhamnus prinoides* and *Ehrharta erecta.*

Geology, Soil & Hydrology Recent sandy-clayey alluvial deposits rich in salt occurring on mudrocks and sandstones of the Adelaide Subgroup (Beaufort Group of the Karoo Supergroup) that support soils typical of Ia land type. Torrential convectional rains in summer cause sudden flood surges which remodel the riverbed and adjacent alluvium.

Climate Transitional, bimodal (equinoctial) rainfall patterns with peaks in March (major) and November (minor). Climate is subarid on the whole, with overall MAP of 243 mm (range from 165 mm in the Gamka Karoo basin to 430 mm in the vicinity of Bedford). Overall warm-temperate regime, with MAT of 16.3°C, ranging from 14.6°C (Upper Karoo) to 18.3°C (upper reaches of Sundays River). Frost occurs frequently in winter. See also climate diagram for AZi 6 Southern Karoo Riviere (Figure 13.2).

Important Taxa **Riparian thickets** Small Trees: *Acacia karroo* (d), *Rhus lancea* (d). Tall Shrubs: *Diospyros lycioides* (d), *Tamarix usneoides* (d), *Cadaba aphylla*, *Euclea undulata*, *Grewia robusta*, *Gymnosporia buxifolia*, *Melianthus comosus*. Low Shrub: *Asparagus striatus*. Succulent Shrubs: *Lycium cinereum* (d), *Amphiglossa callunoides*, *Lycium hirsutum*, *L. oxycarpum*. **Rocky slopes of river canals** Graminoid: *Stipagrostis namaquensis* (d). **Alluvial shrublands & herblands** Low Shrubs: *Ballota africana*, *Bassia salsoloides*, *Carissa haematocarpa*, *Pentzia incana*. Succulent Shrubs: *Malephora uitenhagensis* (d), *Salsola aphylla* (d), *S. arborea* (d), *Drosanthemum lique*, *Salsola geminiflora*, *S. gemmifera*. Graminoids: *Cynodon incompletus* (d), *Cenchrus ciliaris*, *Cyperus marginatus*. **Reed beds** Megagraminoid: *Phragmites australis* (d).

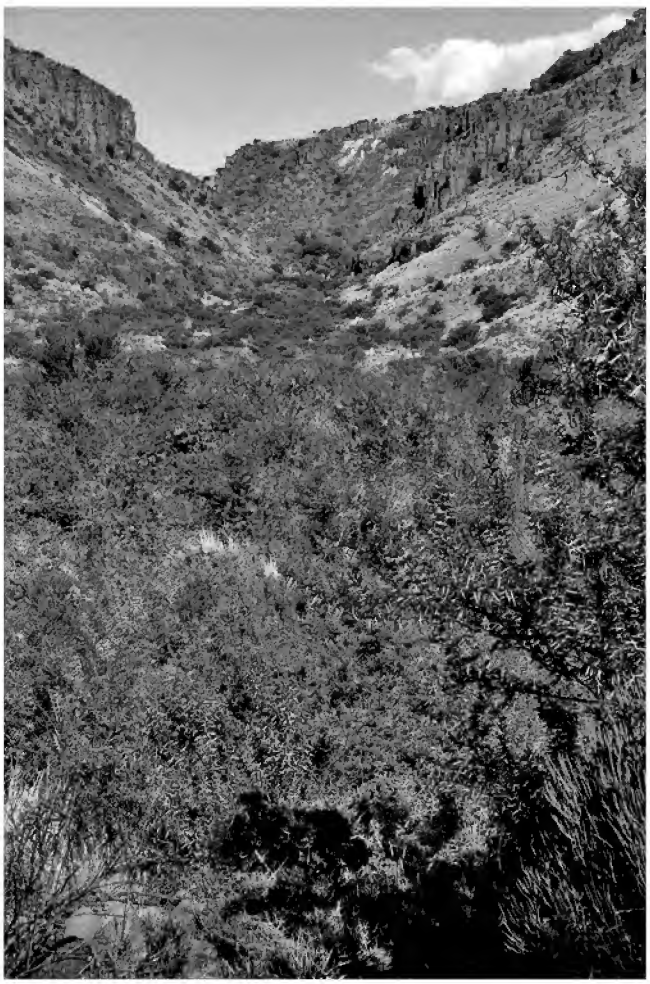

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Figure 13.34 AZi 6 Southern Karoo Riviere: *Acacia karroo* thickets on valley alluvium below the Molteno Pass near Beaufort West (Western Cape).

Endemic Taxon **Alluvial shrublands & herblands** Graminoid: *Isolepis expallescens*.

Conservation Least threatened. Target 24%. Only about 1.5% statutorily conserved in the Karoo National Park as well as in the Aberdeen, Bosberg, Commando Drift, Gamkapoort and Karoo Nature Reserves and in about 10 private reserves, mainly set up for game farming. Some 12% transformed for cultivation and building of dams, including Beaufort West, Beervlei, De Hoop, Floriskraal, Kommandodrift, Lake Arthur, Leeu-Gamka, Mentz and Vanryneveldspas Dams. Frequent disturbance (floods, concentrated grazing pressure), and associated input of nutrients, increase vulnerability of these habitats to invasion of alien woody species such as *Agave americana*, *Opuntia* species, *Prosopis* species, *Salix babylonica* and *Schinus molle*, and forbs including *Atriplex eardleyae*, *A. lindleyi* subsp. *inflata*, *Cirsium vulgare*, *Salsola kali* and *Schkuhria pinnata.*

Remark 1 Due to the lingering taxonomic problems, the identity of South African species of *Salsola* sect. *Caroxylon* cited in various papers (see below), should be approached with caution.

Remark 2 Plants of drainage lines may be resistant to damage by hail storms. At the Tierberg Karoo Research site, 36 of the 44 species in drainage lines were undamaged after a hail storm, with the remaining species only slightly damaged (Milton & Collins 1989). This contrasted with much higher levels of damage to plants of the surrounding habitats (flats and heuweltjies).

References Acocks (1979), Van der Walt (1980), Palmer (1988, 1989, 1991), Milton (1990), Rubin & Palmer (1996), Brown & Bezuidenhout (2000).

AZi 7 Tanqua Wash Riviere

Distribution Western Cape and (to a smaller extent) Northern Cape Provinces: Alluvia of the Tankwa and Doring Rivers and sheet-wash plains of their less important tributaries embedded within SKv 5 Tanqua Karoo. Altitude ranging from 300–1 000 m.

Vegetation & Landscape Features Deeply incised valleys (sometimes several hundred metres broad) of intermittent rivers supporting a mosaic of succulent shrublands with *Salsola* and *Lycium* alternating with *Acacia karroo* gallery thickets. The broad sheet-wash plains support sparse vegetation of various *Salsola* species, often building phytogenic hillocks interrupting the monotonous barren face of a sheet wash. Occasional rainfalls in early winter result in localised displays of annuals and early flowering geophytes along washes.

Geology, Soil & Hydrology Broad Quaternary alluvial floors and drainage lines filled with recent sediments mostly from eroded Karoo Supergroup sediments. Sodic loamy to sandy soils (Ia land type) are predominantly supported by sediments of the Ecca and Dwyka Groups of the Karoo Supergroup. In the west, rocks of the Devonian Bokkeveld Group (Cape Supergroup) and

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Figure 13.35 AZi 7 Tanqua Wash Riviere: Riparian thickets dominated by *Acacia karroo* and *Salsola arborea* with fringing alluvial gannabosveld along the Tankwa River.

in the east, the Permian Adelaide Subgroup (Karoo Supergroup) also support these soils. The run-off in these habitats is very low and spread over large areas.

Climate Region characterised by arid to hyperarid climate, with MAP ranging between 100 mm and 170 mm (lowest long-term average is 72.3 mm for Elandsvlei on the Tankwa River). Overall MAP 162 mm, mainly falling in autumn and winter. Mean daily maximum and minimum temperatures are 32.5°C and 3.0°C for January and July, respectively. Overall MAT is slightly higher than 17°C. Due to basin macrotopography the occurrence of frost is fairly frequent. See also climate diagrams for AZi 7 Tanqua Wash Riviere (Figure 13.2) and SKv 5 Tanqua Karoo (Figure 5.65 in Chapter on Succulent Karoo in this book).

Important Taxa **Riparian thickets** Small Tree: *Acacia karroo* (d). **Alluvial shrublands & herblands** Low Shrub: *Galenia africana*. Succulent Shrubs: *Lycium cinereum* (d), *Malephora luteola*, *Salsola arborea*, *Sarcocornia mossiana* agg. Geophytic Herbs: *Moraea speciosa*, *Tritonia florentiae*. Graminoids: *Cladoraphis spinosa*, *Stipagrostis obtusa*. **Sheet washes** Succulent Shrubs: *Augea capensis*, *Salsola aphylla*. Herbs: *Euryops annuus*, *Gazania lichtensteinii*, *Osteospermum pinnatum*, *Ursinia nana*.

Endemic Taxa **Alluvial shrublands & herblands** Herbs: *Limonium* sp. nov. (*Mucina 310104/1* STEU). **Sheet washes** Succulent Shrub: *Salsola ceresica* (d).

Conservation Least threatened. Target 19%. About 13% statutorily conserved in the Tankwa National Park and in some private reserves (Inverdoorn, Jakkalsfontein, Uintjieskraal, Groote Kapelsfontein, Vaalkloof). About 3% already transformed for cultivation or dam building (Oudebaaskraal Dam and Swartkop se Dam). Alien *Atriplex lindleyi* subsp. *inflata* and *Prosopis* species can become frequent in places.

Remarks We acknowledge that this unit is of heterogeneous character at present and the ecological and floristic relationship between the *Acacia karroo*-dominated riparian vegetation on the one hand and the *Salsola*-dominated sheet-wash vegetation on the other, deserves re-evaluation in the light of new data still to be collected.

Reference Rubin (1998).

AZi 8 Muscadel Riviere

Distribution Western Cape Province: River alluvia of the lower Breede River (between Worcester and Bonnievale) as well as those embedded within the western Little Karoo (Montagu area) and eastern Little Karoo (the rivers draining the basin around Oudtshoorn). Altitude 150–600 m.

Vegetation & Landscape Features Flat, in places very broad alluvia originally supporting a complex of riverine thickets dominated by *Acacia karroo* and accompanying succulent gannabos (*Salsola* species) and low vygie shrublands. Today the typical landscape view of these alluvia is dominated by extensive vineyards and orchards, with a narrow alley of alien woody species (*Eucalyptus* species, *Salix babylonica*) fringing the riverbanks.

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Figure 13.36 AZi 7 Tanqua Wash Riviere: Gannabos (*Salsola ceresica*) on sparsely vegetated sheet wash-plain in the desert-like western part of Tankwa National Park (Western Cape).

Geology, Soil & Hydrology Recent sandy and clayey alluvial (riverine) sediments mostly derived from the clastic sediments of the Jurassic-Cretaceous Uitenhage Group supporting soils typical of la land type. These alluvial habitats frequently suffer from devastating floods occurring especially with the first cold western frontal systems bringing torrential rain to the Cape (such as recently in 1981, 2002, 2004 and 2005).

Climate The regional climate diagram for this unit suggests almost evenly spread precipitation. However, winter rainfall prevails in the western part of the region and becomes nonseasonal towards the eastern limits of the distribution of this vegetation type (eastern Little Karoo). MAP is low (210 mm; range 220 mm in the rainshadow of the Langeberg to

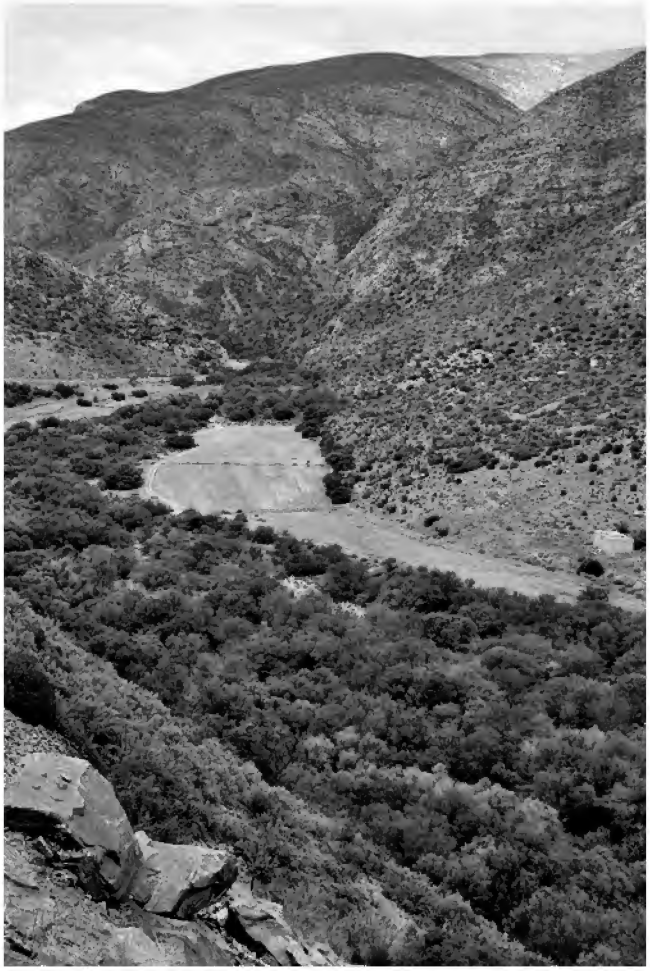

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Figure 13.37 AZi 8 Muscadel Riviere: Alluvial thicket (with dominant *Acacia karroo*) at the bottom of the Huis River in the Huisrivier Pass west of Calitzdorp. Part of the alluvium has been cleared for agriculture.

368 mm in the Breede River Valley) due to the rainshadow effect from the surrounding mountain ranges of the Cape Fold Belt. The region is characterised by relatively high MAT (17.9°C; range 16.0°C in Breede River Valley to 17.2°C near Willowmore) and particularly hot summers (with temperatures reaching above 40°C (especially in Worcester). See also climate diagram for AZi 8 Muscadel Riviere (Figure 13.2).

Important Taxa **Riparian thickets** Trees: *Acacia karroo* (d), *Salix mucronata* subsp. *mucronata* (d), *Rhus lancea*. **Alluvial shrublands & herblands** Tall Shrubs: *Cliffortia strobilifera, Melianthus comosus*, *Tamarix usneoides*. Low Shrubs: *Galenia africana* (d), *Pentzia incana* (d), *Atriplex vestita* var. *appendiculata*, *Chrysanthemoides incana*, *Polygala virgata* var. *virgata*, *Pteronia oblanceolata*. Succulent Shrubs: *Malephora luteola* (d), *Salsola aphylla* (d), *S. arborea* (d), *Bassia salsoloides, Lycium arenicola*, *Suaeda fruticosa, Zygophyllum sessilifolium*. Herb: *Berkheya spinosa*. Succulent Herb: *Psilocaulon junceum*. Graminoids: *Ehrharta calycina*, *E. delicatula*. **Reed beds** Megagraminoids: *Phragmites australis* (d), *Typha capensis* (d).

Endemic Taxon **Alluvial shrublands & herblands** Herb: *Pelargonium citronellum*.

Conservation Endangered. Target 16%. Small patches of this vegetation are protected in the Vrolijkheid Nature Reserve near McGregor (Van der Merwe 1977a) and Kammanassie Nature Reserve (Cleaver et al. 2005) as well as on private land (Greylands, Die Poort). More than 60% already transformed for cultivation (vineyards, orchards) or road building. Aliens *Arundo donax*, *Atriplex lindleyi* subsp. *inflata*, *Chenopodium* species, *Datura* species, *Prosopis glandulosa*, *Ricinus communis*, *Schinus molle*, *Tamarix chinensis* and *T. ramosissima* cause local infestations.

Remark 1 The classification of the '*Calpurnia intrusa-Rhus pallens* Woodland' by Cleaver et al. (2005) described from streambanks of the Vermaaks River (Kammanassie Mountains, eastern Little Karoo) from altitudes 543–675 m remains only tentative. Two communities described within this woodland show transitional character between riparian thickets of the Muscadel Riviere on the one hand and eastern facies of Cape thickets (see chapter on the Fynbos Biome in this book) on the other.

Remark 2 The name of this unit celebrates the marvellous sweet fortified wines (mainly muscadel, but also local port wine) made from grapes grown on the alluvial soils of the summer-hot Robertson Karoo and Little Karoo.

References Joubert (1968), Van der Merwe (1977a), Vlok (2002), Cleaver et al. (2005).

AZi 9 Cape Inland Salt Pans

Distribution Western and Eastern Cape (to smaller extent) Provinces: Jakkalsrivier Valley between Graafwater and Lambert's Bay, Rocher Pan and other pans near Dwarskersbos (near Velddrif), Soutpan near Yzerfontein, Rondevlei, Paardevlei, Noordhoek (all near Cape Town), salt vleis of the Agulhas Plain, Zoutpan and several other smaller salt pans in the Albertinia region (Zoutpan, Melkhoutfontein, Vogelvlei). We also include saline habitats near Worcester and an extensive system of saline alluvia, saline floodplain flats (Karsrivier) and slope saline scars scattered around the Overberg region (e.g. the vicinity of Napier, Bredasdorp, Stormsvlei and Swellendam). These pans occur

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Figure 13.38 AZi 9 Cape Inland Salt Pans: A salt pan on the Agulhas Plain (Overberg region, Western Cape) housing sparse population of an undescribed species of *Salicornia* (Chenopodiaceae) and local endemic *Limonium kraussianum* (Plumbaginaceae).

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Figure 13.39 AZi 9 Cape Inland Salt Pans: Small-scale hypersaline pans near Yzerfontein on the Cape West Coast. Vegetation is dominated by *Sarcocornia natalensis* var. *affinis*, *Suaeda inflata*, *Plantago crassifolia* complex, *Frankenia repens*, *Salicornia meyeriana*, *Sporobolus virginicus* and *Limonium equisetinum*.

Polypogon monspeliensis, *Prionanthium pholiuroides*, *Tribolium hispidum*.

Endemic Taxa Succulent Shrubs: *Disphyma dunsdonii* (d), *Drosanthemum salicola*, *Lampranthus salicola*. Herbs: *Dymondia margaretae* (d), *Limonium anthericoides*. Succulent Herb: *Dorotheanthus clavatus*. Aquatic Herb: *Pseudalthenia aschersoniana*.

Conservation Vulnerable. Target 24%. Some 20% statutorily conserved in the Agulhas and West Coast National Parks as well as in the Soetendalsvlei and Rocherpan Nature Reserves. Furthermore, almost 3% enjoys protection on private land (Rietvlei, Rhenosterkop). More than 20% has been transformed for cultivated land, mines (in the past some of the pans near Albertinia were exposed to salt mining; Muir 1929) or by urban sprawl. Alien (Australian) herbaceous *Atriplex* species show invasive behaviour in places.

References Muir (1929), Noble & Hemens (1978), Van Rooyen (1981), Olivier (1983), Gray (1997), Harding et al. (2000).

as far east as the broader surrounds of the Nelson Mandela Metropole (Soutpan near Dispatch and smaller pans near Uitenhage, Port Elizabeth and Addo). Altitude ranging from 0–150 m, with few isolated pans at around 500 m.

Vegetation & Landscape Features Small depressions dominated by low succulent scrub composed of creeping chenopods and salt-tolerant herbs and grasses. The saline Overberg alluvia are dominated by a low succulent shrub, *Sarcocornia mossiana*.

Geology, Soil & Hydrology Originally, most of the saline pans were coastal lagoons but they became dry after having been cut off from the sea—they may become temporarily flooded by winter rains and remain mostly dry in summer. Some of the smaller salt pans along the coast might have originated through deflation processes on easy-eroding coastal calcrete. The pans in the Overberg region are mostly on Bokkeveld Group shales as well as the much younger sandstone and limestone of the Bredasdorp Group nearer the coast. The saline alluvia of some Overberg rivers were formed by sediments that originated from erosion scars of salt-bearing Bokkeveld shale.

Climate The occurrence of Cape inland salt pans spans typical winter-rainfall (West Coast) and transitional (winter-summer) rainfall regions (Port Elizabeth and Grahamstown areas). MAP ranges from 278 mm (Langebaan) to 627 mm (Humansdorp), while the range of MAT is less pronounced: 15.9°C for the Overberg to 17.5°C for the Sundays River Valley. The ocean has an ameliorating effect on temperature patterns in hot, dry summers. See also climate diagram for AZi 9 Cape Inland Salt Pans (Figure 13.2).

Important Taxa Low Shrubs: *Morella cordifolia*, *Orphium frutescens*, *Senecio halimifolius*. Succulent Shrubs: *Sarcocornia capensis* (d), *S. mossiana* complex (d), *Atriplex cinerea* subsp. *bolusii*, *Lycium cinereum*, *Sarcocornia pillansii*, *Suaeda inflata*. Herbs: *Frankenia repens* (d), *Limonium equisetinum* (d), *L. kraussianum* (d), *Chironia baccifera*, *C. decumbens*, *C. tetragona*. Succulent Herbs: *Malephora luteola* (d), *Plantago crassifolia* complex (d), *Sarcocornia natalensis* (d), *Halopeplis amplexicaulis*. Graminoids: *Chondropetalum microcarpum* (d), *C. nudum* (d), *Sporobolus virginicus* (d), *Elegia verreauxii*, *Ficinia lateralis*, *F. ramosissima*,

AZi 10 Highveld Salt Pans

Distribution Northern Cape, Eastern Cape, North-West, Free State and Gauteng Provinces: Pans scattered on broad Grassland/Karoo and Grassland/Savanna interface roughly between Mafikeng/Koster in the north and Britstown/Middelburg in the south. The highest concentrations of pans are found around Dealesville, Bultfontein, Wesselsbron, Delareyville and Petrusburg. The average size of the playas in the western Free State is 0.2 km^2, with a number of the largest ones (e.g. Florisbad Pan and Annaspan) measuring several kilometres across (Goudie & Thomas 1985). Altitude ranging from 1 000–1 600 m.

Vegetation & Landscape Features Depressions in plateau landscape containing temporary (and less frequently also permanent) water bodies. Central parts of the pans often seasonally inundated and sometimes with floating macrophyte vegetation or the vegetation cover develops on drained bottoms of the pans and forms typical concentric zonation patterns. On the pan edges open to sparse grassy dwarf shrubland may develop, especially when the pan is under heavy grazing pressure.

Geology, Soil & Hydrology The bottoms of the pans are usually formed by shales of the Ecca Group giving rise to vertic clays. The environment of the pans undergoes dramatic changes from freshwater systems during the wet season to saline systems as the dry season progresses and evaporation intensifies. Wind erosion is of particular significance during the dry season, when the playa basin is dry and marginal vegetation is short and sparse (Allan et al. 1995). Dense dust can reach several thousand metres into the air under such windy conditions.

Climate These salt pans occur in arid and semi-arid elevated regions of the Highveld, receiving less than 500 mm rain per year. Overall MAP 400 mm (range from 275 mm in the Upper Karoo to 654 mm in Gauteng). Characterised by thunderstorms leading to high water run-off and low soil absorption. The climate pattern spans bimodal (equinoctial) to typically summer-rainfall in the northeastern regions. The overall MAT of 16.7°C (range 14.3°C near Aliwal North to 18.3°C near Mafikeng). Frequent incidence of frost corresponds to high thermic

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Figure 13.40 AZi 10 Highveld Salt Pans: Salt pan at Hutchinson (Northern Cape).

continentality. See also climate diagram for AZi 10 Highveld Salt Pans (Figure 13.2).

Important Taxa Low Shrubs: *Atriplex vestita*, *Felicia filifolia*, *F. muricata*, *Nenax microphylla*, *Nestlera conferta*, *Pentzia globosa*, *P. incana*. Succulent Shrubs: *Salsola glabrescens* (d), *Lycium cinereum*, *Malephora herrei, Suaeda fruticosa*, *Titanopsis hugo-schlechteri*. Megagraminoids: *Cyperus congestus*, *Phragmites australis*, *Typha latifolia*. Graminoids: *Chloris virgata* (d), *Cynodon dactylon* (d), *C. transvaalensis* (d), *Cyperus laevigatus* (d), *C. marginatus* (d), *Diplachne fusca* (d), *Eragrostis bicolor* (d), *E. chloromelas* (d), *E. plana* (d), *Hemarthria altissima* (d), *Juncus rigidus* (d), *Panicum coloratum* (d), *P. laevifolium* (d), *P. schinzii* (d), *Setaria incrassata* (d), *Andropogon eucomus*, *Aristida adscensionis*, *Brachiaria marlothii*, *Cyperus longus*, *C. rigidifolius*, *Echinochloa holubii*, *Eleocharis palustris*, *Enneapogon desvauxii*, *Eragrostis curvula*, *E. micrantha*, *E. obtusa*, *E. stapfii*, *Fuirena coerulescens*, *F. pubescens*, *Juncus exsertus*, *Scirpoides dioecus*, *Sporobolus albicans*, *S. fimbriatus*, *S. ioclados*, *S. tenellus*, *Tragus berteronianus*, *T. racemosus*. Herbs: *Alternanthera sessilis*, *Amaranthus praetermissus*, *Aponogeton rehmannii, Atriplex suberecta*, *Chenopodium mucronatum*, *Gnaphalium declinatum*, *Mollugo cerviana*, *Phyla nodiflora*, *Platycarpha parvifolia*, *Pterodiscus speciosus*, *Senecio reptans*. Succulent Herb: *Zygophyllum simplex*.

Biogeographically Important Taxon (Highveld endemic) Herb: *Rorippa fluviatilis* var. *caledonica*.

Endemic Taxon Herb: *Gnaphalium simii*.

Conservation Target 24%. Only very small portion statutorily conserved in the Vaalbos National Park and in the Bloemhof Dam, Soetdoring, Willem Pretorius, Barberspan (a Ramsar site) and S.A. Lombard Nature Reserves. About 4% has been transformed so far, but threats by agriculture, road building, mining and urbanisation are still increasing. Alien plants such as *Atriplex semibaccata*, *Conyza albida*, *Flaveria bidentis*, *Salsola kali*, *Schkuhria pinnata*, *Sonchus oleraceus*, *Spergularia rubra*, *Tagetes minuta*, *Verbena brasiliensis* and *Xanthium* species (Cilliers & Bredenkamp 2003, Janecke et al. 2003) have been recorded in the vegetation of these salt pans.

Remark 1 In the northeastern regions of the NKu 4 Eastern Upper Karoo (e.g. along the upper Orange River Valley between Aliwal North and Petrusville, in the broad area of Middelburg, Rosmead, Hanover and Colesberg) eroding calcrete outcrops in wide pan-like depressions form an interesting microhabitat. It is characterised by shallow, white, powdery and highly alkaline soils (Werger 1980 measured pH values above 8) usually supporting dominants similar to those of true salt pans, including *Salsola glabrescens*, *Zygophyllum incrustatum*, *Eragrostis truncata*, *Sporobolus* species and *Pentzia globosa* as well as some odd vygies such as *Trichodiadema pomeridianum*, *Titanopsis schwantesii* and *Delosperma 'ornatulum'* (Werger 1980, p. 77).

Remark 2 The vegetation of the Highveld Salt Pans differs greatly from that of other pan types (Namaqualand Salt Pans, Bushmanland Vloere, Southern Kalahari Salt Pans and Cape Inland Salt Pans) mainly due to the dominance of cyperoids.

Remark 3 Geldenhuys (1982) distinguished the six pan types based on the presence of emergent vegetation—bare, sedge, scrub, mixed grass, closed, and open *Leptochloa* playas.

References Noble & Hemens (1978), Werger (1980), Seaman (1987), Kooij et al. (1990b), Seaman et al. (1991), Breen et al. (1993), Allan et al. (1995), Bezuidenhout (1995), Malan (1998), Janecke (2002), Cilliers & Bredenkamp (2003), Janecke et al. (2003).

AZi 11 Subtropical Salt Pans

Distribution Limpopo, Mpumalanga and KwaZulu-Natal Provinces and in Swaziland: Pans in the subtropical regions of eastern southern Africa, in particular in the Lowveld, Maputaland and northern KwaZulu-Natal. Altitude ranging from 0–1 400 m.

Vegetation & Landscape Features Shallow depressions, often found on old alluvial terraces of rivers, surrounded by zones of bank reeds or low herblands and in more perennial pans also filled with a dense carpet of macrophytic floating vegetation.

Geology, Soil & Hydrology The pans occur on Cenozoic alluvium, sand and calcrete, but also significantly on sediments of the Cretaceous Zululand Group. Large perennial-water pans are found in the alluvia of the Phongolo and Usutu Rivers. During the drier winter period, the water may recede below ground and salt may precipitate on the banks (this especially in the case of small zoogenic pans in the Kruger National Park), the water in the pans consequently becoming brackish and even saline. The salinity of water of some other pans (such as the Nyamithi Pan in the Ndumo Game Reserve) is attributed to leaching of salt from Cretaceous sediments of marine origin (Hattingh & Matthews 2003).

Climate Seasonal, summer-rainfall regime with MAP ranging from 311 mm in the Limpopo Valley to 964 mm in Maputaland. Subtropical temperature regime with MAT ranging from 18.0°C in the Central Bushveld to 22.0°C in Maputaland), with very infrequent incidence of frost (only in marginal areas of contact with the Grassland Biome in the Central Bushveld). See also climate diagram for AZi 11 Subtropical Salt Pans (Figure 13.2).

Important Taxa **Drained pan bottoms** Graminoids: *Cynodon dactylon* (d), *Diplachne eleusine* (d), *Eragrostis rotifer* (d), *Chloris virgata*, *Cyperus indecorus*. Herbs: *Isoetes schweinfurthii, Persicaria senegalensis*. **Pan edges** Megagraminoid: *Phragmites mauritianus* (d). Graminoids: *Digitaria didactyla*, *Echinochloa pyramida-*

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Figure 13.41 AZi 11 Subtropical Salt Pans: A pan near Masinda Camp in the Hluhluwe-iMfolozi Park with a reed bed of *Typha capensis* and resting zebra (*Equus burchellii*).

lis, *Paspalum vaginatum*, *Sporobolus smutsii*. Herbs: *Eclipta prostrata, Marsilea ephippiocarpa, Persicaria hystricula*, *Syngonanthus wahlbergii*. **Pan lakes** Herb: *Ludwigia stolonifera* (d). Aquatic Herbs: *Azolla pinnata* var. *africana* (d), *Ceratophyllum demersum* (d), *Nymphaea nouchali* var. *caerulea* (d), *Potamogeton crispus* (d), *Trapa natans* var. *bispinosa* (d), *Wolffia arrhiza* (d), *Monochoria africana*, *Najas pectinata*, *Nymphaea lotus*. Carnivorous Herb: *Utricularia inflexa* (d).

Endemic Taxon **Pan edges** Aquatic Herb: *Marsilea fenestrata*.

Conservation Least threatened. More than 40% (well over the target of 24%) statutorily conserved in the Greater St Lucia Wetland Park, Ndumo Game Reserve (both Ramsar sites), Kruger National Park as well as in the private Zoutpan Nature Reserve. About 11% has been transformed for mines, cultivation and plantations. Aliens *Cardiospermum halicacabum* and *Argemone ochroleuca* invade edges of some of the pans. Alien floating *Pistia stratiotes* and *Nymphaea lotus* are dominant in some Lowveld pans when filled with water.

Remark 1 Subtropical salt pans have always served as an important source of water (and salt) for ungulates abundant in the Savanna Biome. In winter wild animals teem around the water 'holes' (often natural pans with residual water from the summer), a spectacle attracting thousands of local and overseas tourists.

Remark 2 At least one salt pan has been recognised as a result of a meteorite impact that resulted in a crater, the floor of which later developed into a temporary flooded salt pan. This is the Tswaing Crater (formerly Pretoria Salt Pan) 40 km north of Pretoria and it is 200 000 years old.

References Musil et al. (1973), De Moor et al. (1977), Noble & Hemens (1978), Goodman (1981), Gertenbach (1983), Begg & Carser (1988, 1989), Schmidt (1992), Schmidt et al. (1993), Breebaart & Deutschländer (1997).

8. Credits

The concept of the classification of the inland azonal vegetation units was formulated by L. Mucina with assistance of M.C. Rutherford and L.W. Powrie. These authors have also prepared the first-approach map of the units using land-cover, satellite imagery and digitised topographic maps featuring lakes, pans and major wetlands. Many of the azonal vegetation patches were classified after extensive field work. The Namaqualand salt pans were mapped by A. le Roux, while parts of the coverage for alluvial and freshwater wetlands of the Capensis were provided by A.G. Rebelo, C. Boucher (both within the Fynbos Biome) and J.C. Manning (vernal pools).

The introductory text was written by L. Mucina, with contributions by J. Gerber (Section 5). L. Mucina wrote descriptions of all vegetation units as first author except for AZi 1 and 2, where he assisted A. le Roux. The following colleagues co-authored several descriptions: M.C. Rutherford (AZi 3, 5 and 6), G.J. Bredenkamp (AZa 5 and AZi 10), P.J. du Preez (AZa 4 and AZi 10), J.C. Manning (AZf 2 and AZi 7), E.J.J. Sieben (AZa 1 and 2), H. Bezuidenhout (AZa 3), S.S. Cilliers (AZi 10), J. Gerber (AZf 3), D.B. Hoare (AZa 6) and F. Siebert (AZa 7). The species lists were compiled by L. Mucina with the technical help of L.W. Powrie. The data for the Conservation sections of the descriptions were compiled by L.W. Powrie and the sections on Geology, Soil & Hydrology were corrected by R.A. Ward. M. Rouget, and others within the Directorate of Biodiversity Programmes, Policy & Planning of SANBI, provided quantitative information for each vegetation unit on conservation status and targets, areas currently conserved and areas transformed.

The climate diagrams were prepared by M.C. Rutherford and L.W. Powrie. Most of the photographs were provided by L. Mucina except for those kindly contributed by W.S. Matthews, M.C. Lötter and J.C. Manning. L. Scott, J. Grobbelaar, K. Kobisi, M. Polaki and J.R.U. Wilson provided some less accessible literature sources. C.R. Scott-Shaw and P.S. Goodman provided valuable comments on parts of the text.

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Coastal Vegetation of South Africa

14

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Figure 14.1 Evening mood with *Scaevola plumieri* (Goodeniaceae) on the coastal dunes of Maputaland (northern KwaZulu-Natal).

W.S. Matthews

List of Vegetation Units

Algal Beds 680
AZm 1 Cape Kelp Beds 680

Estuarine Vegetation 681
AZe 1 Arid Estuarine Salt Marshes 681
AZe 2 Cape Estuarine Salt Marshes 682
AZe 3 Subtropical Estuarine Salt Marshes 683

Seashore Vegetation 683
AZd 1 Namib Seashore Vegetation 683
AZd 2 Namaqualand Seashore Vegetation 684
AZd 3 Cape Seashore Vegetation 685
AZd 4 Subtropical Seashore Vegetation 686

Eastern Strandveld 687
AZs 1 Algoa Dune Strandveld 687
AZs 2 Albany Dune Strandveld 688
AZs 3 Subtropical Dune Thicket 689

1. Introduction: Distribution and Azonal Character of Coastal Vegetation

The vegetation of South African coasts owes its origin to two major seas—the Atlantic Ocean and Indian Ocean. These huge water masses not only shape the varied faces of the coast, but function as major factors creating the coastal climate, and indeed the climate of the subcontinent in general. Tides and salt spray are other controlling factors shaping the ecology of coastal habitats. Hence all vegetation units forming part of the coastal vegetation in this chapter and depicted by our Map are those of which the origin, structure and dynamics are a function of the sea and its immediate influence in terms of flooding by sea water, influence of salt spray, formation and re-formation of coastal sediments (beaches, dunes, old dune plumes).

The coastal vegetation of South Africa is very diverse and reflects the vastly different oceanographic and climatic conditions giving rise to a great variety of habitats occurring in this dynamic environment. These habitats result from the manifold and intricate interactions between sea and air temperature, geology and local topography, wind patterns and deposition of sand and salt, and of tidal regime. The coastal band forms a patchy series of offshore kelp 'forests' (in the west), sandy beaches, sand dunes and rocky headlands, interrupted by man-made beach fronts, harbours or estuaries. The coast extends from arid Alexander Bay (on the Northern Cape/Namibian border) on the Atlantic coast, along the semi-arid West Coast, around the famous Cape of Good Hope and Cape Agulhas (southernmost point of the African continent), further along the southern and eastern Indian Ocean seaboards as far as tropical Maputaland (northern KwaZulu-Natal) shared by South Africa and neighbouring Mozambique.

The macro-patterns of the coastal vegetation of South Africa are controlled by large-scale atmospheric systems over southern Africa and by the oceanography of the adjacent oceans. The climate is largely temperate to subtropical and is affected by two major sea currents—the cold north-flowing Benguela Current of upwelling inshore waters along the West Coast and the warm south-flowing Mozambique Current (extending southwards as the Agulhas Current) bringing equatorial waters with it and lapping the Indian Ocean coasts of South Africa (Lutjeharms 1998, Schumann 1998) (Figure 14.2). Due to its subtropical geographical position, South Africa's weather patterns are dominated by the interaction of three major pressure systems. As a result, the major winds along the coast are bidirectional and quasiparallel to the coastline. Southerly winds alternate with northwesterly winds on the West Coast, westerly with easterly winds along the South Coast, and southwesterly with northwesterly winds on the East Coast (Tinley 1985, Stone et al. 1998).

The coastline traverses a number of climatic regions, from the hyperarid and cool-temperate climate of the southern Namib coast at Alexander Bay, the semi-arid cool-temperate climate of the coast west of Cape Agulhas, the warm-temperate climate (with various precipitation regimes) to the moist subtropical coast of KwaZulu-Natal. The coastal extremes in temperature are in general dampened by the influence of marine air, increased cloud cover, high atmospheric humidity, the cooling effect of sea breezes, and the cold and warm currents flow-

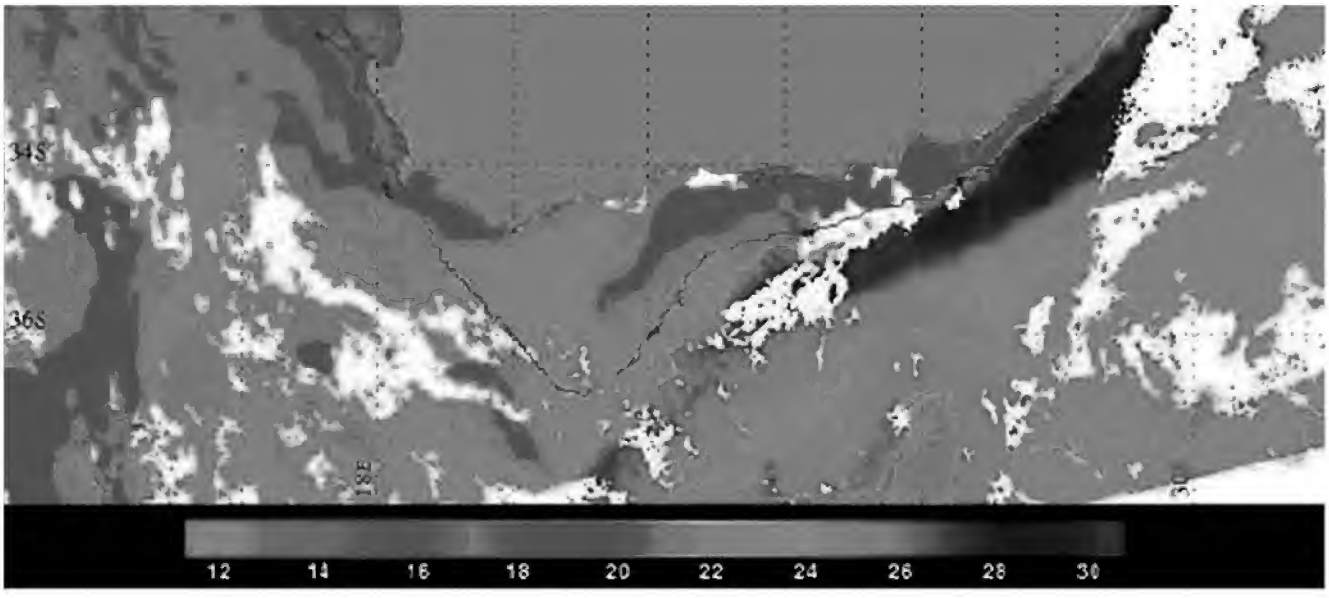

Figure 14.2 A high resolution NOAA-14 AVHRR thermal infrared composite satellite image (16-18-23 December). Colours show the sea temperatures (see the scale). The warm current along the southern and eastern coasts is the Agulhas Current, while the dark blue colour on the West Coast indicates the position of the Benguela Upwelling System. The dark line extending into the sea south of Cape Agulhas shows the edge of the continental shelf. Clouds appear white. (Courtesy of the American Meteorological Society; Rouault et al. 2002. Weather & Forecasting 17: p. 656.)

ing offshore. The West Coast is characterised by a low winter rainfall which decreases rapidly northwards, from 567 mm in Cape Town (Sea Point) to 449 mm at Koeberg (barely 25 km to the north) to 45 mm at Alexander Bay. The East Coast experiences rainfall increasing from 800 mm in the south to 1 300 mm at the border with Mozambique (compare various climate diagrams for our vegetation units: Figure 14.3).

The concept of azonality of coastal vegetation follows the same principles of zonality of vegetation as discussed in Chapter 13. Although the influence of (macro)climate is undeniable in shaping the biogeographical patterns within coastal vegetation, the ecological factors delimiting this vegetation from the zonal vegetation of the neighbouring biomes prevail. Tidal regime (combined with salt stress and inoxia resulting from submergence in water) is the major complex factor controlling the vegetation of salt marshes. On the rocky headlands the major habitat conditions are the lack of, or extremely impeded, soil development, combined with air-borne salt deposition, and disturbance brought about by frequent and strong desiccating winds. The dunes can be seen as an azonal substrate subject to heavy desiccation due to fast drainage (with good water storage properties but at depths beyond many plants on the often mobile substrate), relentless desiccating coastal winds, and extreme exposure to sun irradiation due to the high albedo associated with low biomass cover and light-coloured sand. The soils are rich in deposited marine salt, buried decomposing animal bodies and plant debris, and a high content of alkaline substances due to concentration of hard body skeletons of marine organisms (macroshells of marine molluscs, microcysts of dinoflagellates, etc.).

Strictly speaking, the concepts of zonality as defined by Walter (1964, 1973; see Chapter 13 in this book) should not apply to marine vegetation (such as seaweed and seagrass communities). The global patterns of marine vegetation are directly controlled rather by temperatures of the sea (to a large extent still under the influence of the local and regional climate) and salt concentration (Den Hartog 1970, 2003, Breeman 1988, Bolton & Anderson 1997) than by climatic parameters such as air temperature, precipitation seasonality and the like.

2. Origins of South African Coastal Features

The coasts of South Africa are as old as the African continent itself—logically their origin roots in the split of Africa from the southern supercontinent Gondwanaland (started 130 mya and fully accomplished around 60 mya). Changes in sea level along the South African coast during the Cenozoic (ca. 65–2 mya) reflect global levels and geological timescales closely. Transgressions, stillstands and regressions can therefore be dated internationally. The record of changes in sea level differs regionally because of, for instance, more complex geological conditions along the South Coast as compared to the West Coast, but coincides according to vertebrate and invertebrate fossil finds. The greatest differences between the current and palaeo-coastlines (dated back to around 5 mya) are found in the broad surrounds of Cape Town, around the present Cape Agulhas, and in Maputaland. Along most of the more steeply sloping coastal zones of the southern and eastern Cape with their incised river valleys, these features are less prominent (Marker 1988). In the Langebaan region four well-defined higher Cenozoic shorelines can be distinguished from the Late Tertiary, chronologically arranged at approximately 30 m (Late Miocene), 90 m, 50 m and 20 m (Late Pliocene) above current MSL.

The high sea level (about 25 m higher than today) of two important marine transgressions 5 mya and 1.5 mya led to the isolation of the Cape Peninsula and its split into two islands separated from the mainland by the broad Cape Flats Seaway and a narrow Fish Hoek Channel (Compton 2004). During the LGM (about 20 000 BP) the sea level was more than an estimated 125 m lower than today (due to much of the planet's freshwater stock locked in polar ice caps). As a result, the coastline of the southwestern Cape migrated up to 100 km seawards, exposing broad dryland benches around Cape Point, draining False Bay and exposing the continental shelf southwards beyond the present Agulhas Plain. The fossil canyon of the Breede River has been traced for some 70 km across the present sub-

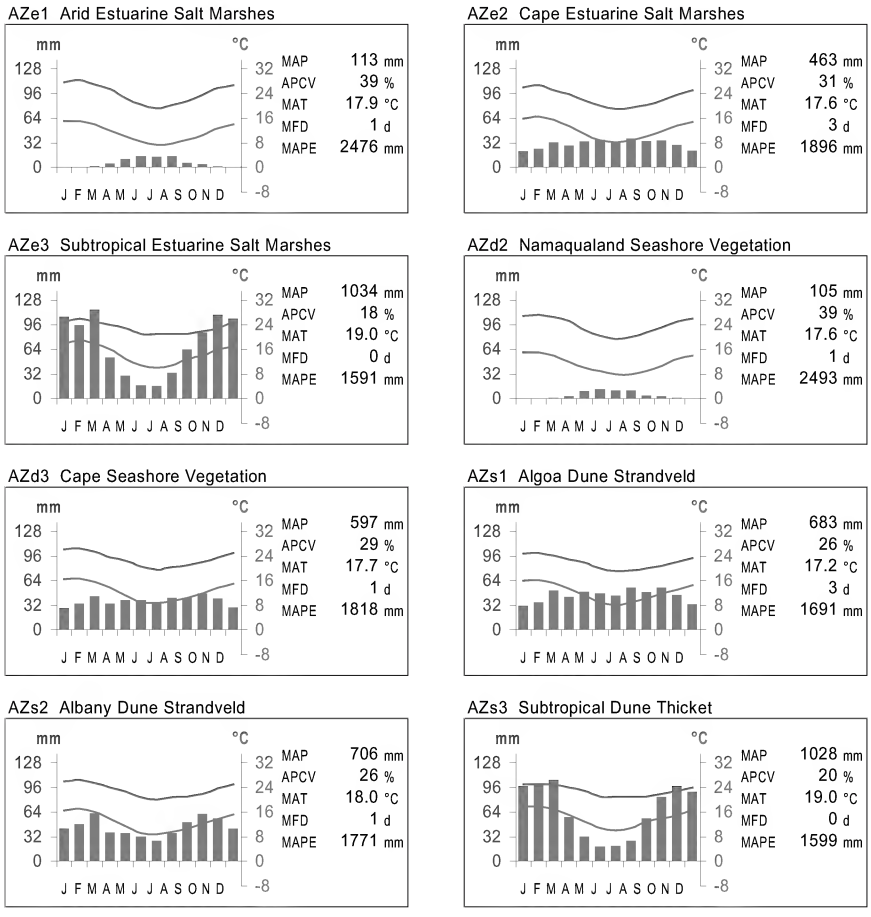

Figure 14.3 Climate diagrams of the coastal vegetation units (excluding AZd 1 Namib Seashore Vegetation due to lack of data, but see Figure 6.2 for climate diagram of Alexander Bay). Blue bars show the median monthly precipitation. The upper and lower red lines show the mean daily maximum and minimum temperatures, respectively. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days (days when screen temperature was below 0°C); MAPE: Mean Annual Potential Evaporation.

merged Agulhas Shelf and similar canyons have been mapped for the larger rivers such as the Gamtoos on the East Coast (Marker 1988).

The coastal plains of Maputaland have also been witness to numerous marine transgressions and regressions which have recurrently altered the shape of these coasts. For instance, during the Last Interglacial (Eemian, also known as oxygen-isotope stage 5e) with sea level being approximately 5 m higher than today, an offshore barrier archipelago evolved which isolated a back-barrier environment comprising intertidal sand-flats, reefs and tidal channels. The last 9 000 years witnessed numerous changes in sea level in Maputaland shaping the current lagoon systems such as Kosi Bay and St Lucia and turning original salt-water lakes into freshwater bodies such as Lake Sibaya (Wright et al. 2000). As can be expected, estuarine landforms are essentially features that develop along transgressive shorelines following a rise in sea level because of the higher energy wave action depositing sediments and building sand bars across river mouths. These geomorphic processes were paralleled in similar fashion in the shaping of the Wilderness lake system and by development of other lagoons along the southern and western coasts (Reddering & Rust 1990).

Throughout the Cenozoic, the southeastern coast of southern Africa has been characterised by a long series of marine transgressions and regressions, induced both by continental uplift (see Partridge et al. 1995 for an exhaustive summary), seaward marginal tilting of the subcontinent (De Wit 1993) and glacio-eustatic sea level movements. These increases and decreases occurred in response to accumulation and melting of ice caps (Maud & Botha 2000). Of all the marine transgressions revealed after the Mid-Miocene, the Early Pliocene transgression reached the maximum elevation of 80–90 m (Haq et al. 1987). In the Langebaan region a major Middle to Late Miocene transgression formed a 30 m palaeo-shoreline along which the phosphatic layers were deposited in the inundated valleys along the coastline that preserved the fossils at the Langebaan Fossil Park. The later regression that produced the maximum 90 m shoreline left present hilltops as isolated islands and the mouth of the Berg River entering the sea near present-day Langebaan, only to shift northwards with the rising sea level (Erasmus 2005).

The current South African coasts are a mosaic of various geologies—a chronicle of geological history of the subcontinent. There are hard rocky coasts built of sandstone and hard mudstones (Silurian-Devonian Table Mountain Group, Silurian Natal Group), granites (mostly Cape), Malmesbury shales and Beaufort sandstones and mudstones (see for instance Marker 1988, Boucher & Le Roux 1993, Taylor & Boucher 1993, Weisser & Cooper 1993 for regional accounts of coastal geology). These older geological formations are contrasted, however, by much younger unconsolidated Cenozoic sediments of Tertiary age deposited in the coastal lowlands as sands of littoral marine, estuarine, lacustrine and aeolian origin and reaching prominence along the western and southern Cape and Maputaland in the extreme east (see Maud 2000, Maud & Botha 2000, Compton 2004 for summarising accounts for various stretches of the South African coast).

The present-day estuaries at South African river mouths are still younger geological phenomena, both due to the dynamic character of the sedimentation cycles and the evolutionary changes in the subcontinental drainage network (De Wit 1993, 1999) which often resulted into decay and emergence of new river mouths. The major erogenetic uplift and marginal tilting of the eastern hinterland of the subcontinent in the Late Pliocene caused severe marginal erosion along the southeast coasts, which destroyed all vestiges of truly estuarine deposits older than the Pleistocene (Maud 2000). Global climate change during the next 100 years is expected to cause a considerable rise in sea level (around 0.5 m is predicted) because of polar ice-cap melt. The coupled isostatic settling of the crust due to the added weight of water over the wide (especially Agulhas) continental shelf (Reddering & Rust 1990) may exacerbate the effect of the rising sea levels in estuaries and coastal lakes by a further 25%.

3. Ecology of Coastal Habitats

Since the sea is the major source of habitat variability on the coast, the character and location of coastal habitats is very much dependent on the distance from the seashore (in terrestrial habitats such as coastal dunes) or by the intensity of influence of sea (tidal) waters (in semi-aquatic habitats such as salt marshes). In South Africa, coasts and the sea enjoy the interest of scientists and the public. A number of scientific compendia (Day 1981a: estuaries, McLachlan & Erasmus 1983: beaches), review papers (Brown & Jarman 1978: coastal marine habitats, Boucher & Le Roux 1993, Taylor & Boucher 1993, Weisser & Cooper 1993, Lubke et al. 1997, Lubke 2004: coastal vegetation, Bolton & Anderson 1997: marine vegetation), reports and series (Heydorn & Tinley 1980: estuaries, Tinley 1985: dunes, McGwynne & McLachlan 1992: coastal management), but also popular and semipopular books on coastal and sea biota (Branch & Branch 1981, Lubke et al. 1988, Lubke & De Moor 1998) contain valuable information and sources on ecology and biodiversity of the marine and coastal flora and vegetation. Therefore, we shall concentrate only on selected features of the coastal vegetation, especially those that underlie the current classification and mapping of these ecosystems.

3.1 Aquatic and Semi-aquatic Habitats

3.1.1 Algal Beds

Algal beds are a very special habitat, usually straddling the ecotone between the sea and firm land. Coastal tidal pools, found on rocky platforms in the intertidal zones (Figure 14.4) are a prime habitat for marine algal assemblages. Tidal dynamics create a series of habitats from those permanently under water to those being intermittently exposed during the ebb. Fascinating zonation systems are formed along the tidal gradients (Bolton & Anderson 1997). Kelp beds are formed inshore and although they are exposed to tidal fluctuations, they stay permanently under water. They reach as far as 3 km from the seashore into the open sea, but they prefer sheltered coastal coves.

Further details on ecology, patterns and processes, utilisation and other relevant aspects related to algal beds and marine vegetation in general can be found in in-depth reviews such as those by Branch & Branch (1981) and Bolton & Anderson (1997).

3.1.2 Estuaries

Ecology of Estuaries: Tides and Salinity

Estuaries are places where freshwater of a river meets the salt water of the sea or coastal lagoon and where gradual transitions in physical, chemical and biological characteristics between freshwater and seawater ecosystems can be found (Day 1980, 1981a, Ketchum 1983, Heydorn 1989a). Dynamics of water flows (tides and river input), mixing of fresh and salt waters, erosion and sedimentation processes mould an intricate system of microhabitats making up the phenomenon

called 'estuary' (Figure 14.5). There have been many types of estuaries described based on origin and hydrodynamics (see Day 1981a, Ketchum 1983 for accounts of systems), but for our purpose we shall consider only two major types of estuaries—the open and closed (permanently and temporarily). This simple classification system is supposed to reflect the role and strength of tidal influence in controlling the patterning and dynamics of estuarine habitats.

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Figure 14.4 Salt marshes of the Kromme River Estuary at St Francis Bay, dominated by chenopods such as *Sarcocornia perennis* complex, *Salicornia meyeriana* and *Chenolea diffusa*.

Estuaries are usually composed of sublittoral marine zones (permanently under water), intertidal flats experiencing different periods of flooding (depending on the local tidal conditions and topography), and supratidal terraces. The supratidal zone refers to the area that is situated above the intertidal zone, formerly part of flooded flats and mostly outside the direct tidal influence except for spring tide and other associated high water levels. The floodplain is the area adjacent to the supratidal and is elevated above the rest of the estuary. This area is normally covered with water only during large flood events. In estuaries where the mouth closes the intertidal habitat is reduced or absent. Sometimes freshwater seeps and water springs add a new facet to the estuarine habitat mosaic (see O'Callaghan 1994a, Mucina et al. 2003 for sources on South African salt marshes and related habitats). In places, salt pans are also present, usually indicating the position of tidal creeks a long time ago and currently severed from the contact with the sea.

At the low tidal boundary, some sublittoral tidal flats experience exposure to terrestrial conditions at the lowest tidal conditions (neap tide). Here seagrass 'meadows' are built by rhizomatous graminoids ('rosulate herbs' *sensu* Cook 2004) of the families Zosteraceae (*Zostera capensis*) and Cymodoceaceae (*Halodule*, *Thalassodendron*). Calm brackish pools of deeper creeks within the estuaries often house submerged macrophyte vegetation tolerant of some levels of salinity. Typical aquatic plants of these habitats include salt-tolerant charophytes of the genera *Chara*, *Lamprothamnium*, *Nitella* and *Tolypella* as well as short-lived angiosperms of the genera *Ruppia*, *Althenia*, *Pseudalthenia* and *Zannichellia*. The life form of all these organisms is classified as 'vittate herb' by Cook (2004). Submerged macrophytes such as pondweed (*Potamogeton pectinatus*) occur only in small freshwater-dominated estuaries.

Intertidal *Spartina maritima* meadows (Pierce 1979, 1982) are a common sight in open estuaries, but they are absent from temporarily closed or closed estuaries, which may be attributed to the plant's requirements for tidal flooding and saturated substrates (Adams & Bate 1995).

A study of four Eastern Cape estuaries (Adams et al. 1992) showed that in the temporarily open/closed Seekoei and Kabeljous Estuaries, diversity and cover of emergent macrophytes was lower than that of the permanently open estuaries (Gamtoos and Kromme). This was attributed to the availability of suitable habitat, fluctuating water levels and periodic hypersaline conditions. Grasses were the dominant plants as species such as *Sporobolus virginicus* grow well under waterlogged conditions and can withstand long periods of submergence (Breen et al. 1977). Closed mouth conditions and an increase in water level result in a rapid die-back of succulent plants. When the mouth opens again and the water levels drop, the resident seed banks play an important role in the re-establishment of salt marshes, e.g. *Triglochin* species in the Great Brak Estuary and *Sarcocornia* species in the Seekoei Estuary. Similarly in the Lake St Lucia system, Ward (1976) found that decreases in water levels in open saline or brackish soils led to colonisation by species of genera such as *Salicornia*, *Sarcocornia* and *Atriplex*. When lake levels rose again, these species were killed off since they are intolerant of prolonged inundation.

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Figure 14.5 Algal beds in tidal potholes on the limestone coast of De Hoop Nature Reserve near Arniston, Western Cape.

There are few obvious links between elevation and tidal regime on one hand and salinity on the other. Adam (1990) reported an inverse linear relationship between salinity and elevation, while

maximum salinity peaked just below maximum high-water spring tide level. Adams et al. (1992) found that sediment salinity of the intertidal macrophyte communities was determined by the salinity of the adjacent water body, since these species are daily inundated by tides. Fluctuations in water column salinity would therefore raise and lower sediment salinities, which would influence macrophyte germination and growth. Salt-marsh plants are dominant at salinities between 10 and 35 ppt. Only a few species germinate in salinities greater than 20 ppt. One of the most critical stages in the life cycle of halophytes is the period of germination and establishment. For the successful establishment of plants in saline environments, seeds must be able to remain viable at high salinities and germinate when the salinity is reduced (Ungar 1978, 1982, 1987). The ambient salinity in a salt-marsh system is not influenced only by the tides. De Leeuw et al. (1991) detected the position along a salt-marsh elevation profile above which substrate salinity was affected by climate variables rather than by tidal regime. According to Adams et al. (1992) supratidal macrophytes are usually associated with low moisture content due to limited tidal flushing in this area, thus rainfall and evaporation are more important in influencing the distribution of these species. Occasional events of flooding can result in increased water levels and in flushing out salts from this habitat.

Recent studies have indicated groundwater salinity and depth to groundwater as important determinants for supratidal and floodplain salt marshes (Bornman et al. 2002, 2004a, b). The Olifants Estuary has the largest area of supratidal (143 ha) and floodplain salt marsh (797 ha) on the dry West Coast (Table 14.1). A single species, *Sarcocornia pillansii*, is dominant in this dry saline habitat. Bornman (2002) showed that the survival of the plants was dependent on the utilisation of saline groundwater particularly during the dry period (eight months) of the year. The cover abundance of *S. pillansii* was visibly reduced where the water table was deeper than 1.5 m and/or where the electrical conductivity of the groundwater had a high ion concentration (>80 $mS.cm^{-1}$). Flooding of the estuary is important in lowering the salinity of the water column, which influences groundwater salinity. Any disturbance to this habitat will result in large areas of bare ground as has happened at the mouth of Orange River (Bornman et al. 2004a).

An investigation by Walker (2004) in the East London estuaries (Tyolomnqa to Kei) showed that reeds, sedges and supratidal salt marsh were found in all estuaries. The supratidal salt-marsh communities are similar to those of permanently open estuaries. Species dominance varied depending on salinity. Compared to permanently open estuaries, temporarily open/closed estuar-

Table 14.1 List of available information on South African estuaries with the largest intertidal and supratidal salt marsh areas and the change in area over time. Past cover (ISM & SSM past, in hectares) was estimated from 1937 or 1961 aerial photographs (Colloty et al. 2001), while the present cover (ISM & SSM pres, in hectares) reflects the situation in 1998. All estuaries with present area >20 ha were included. **Reg**: Bioclimatic region (cT: cool-temperate, wT: warm-temperate, Sub: subtropical). **Class**: Classification system (EB: Estuarine Bay, ELS: Estuarine Lake System, PO: Permanently Open, RM: River Mouth, TO/C: Temporarily Open/Closed). **ISM**: Intertidal Salt Marsh. **SSM**: Supratidal Salt Marsh. **TSM**: Total Current Salt Marsh.

Estuary	Locality	Reg	Class	ISM pres	ISM past	SSM pres	SSM past	TSM
Berg	32°46'S/18°09'E	cT	PO	141.8		1536.1		1677.9
Olifants	31°42'S/18°11'E	cT	PO	91.9		940.1		1032.0
Knysna	34°03'S/23°04'E	wT	EB	634.0	406.0	60.0	389.2	694.0
Langebaan	33°07'S/18°03'E	CT	EB	123.3		250.6		373.9
Keiskamma	33°17'S/27°29'E	wT	PO	210.0		91.3	311.8	301.3
Gamtoos	34°00'S/24°56'E	wT	TO/C	40.0	112.5	163.2	245.1	203.2
Great Fish	33°30'S/27°08'E	wT	PO	46.7	47.3	152.3	154.2	199.0
Orange	28°38'S/16°27'E	cT	RM	84.0	290.0	107.8	136.8	191.8
Swartkops	33°57'S/25°38'E	wT	PO	165.0	215.0	5.0	40.0	170.0
Kromme	34°09'S/24°51'E	wT	PO	18.1	17.6	67.2	74.0	85.3
Mhlathuze	28°49'S/32°05'E	Sub	EB	60.0	50.0			60.0
Mtati	33°25'S/27°16'E	wT	TO/C			54.3	69.3	54.3
Duiwenhoks	33°22'S/21°24'S	wT	PO	50.8				50.8
Breede	34°24'S/20°51'E	wT	PO	20.5	22.5	29.6	32.2	50.1
Cefane	32°49'S/28°08'E	wT	TO/C	28.1		21.4		49.5
Goukou	34°23'S/21°25'E	wT	PO	44.2				44.2
Keurbooms	34°02'S/23°23'E	wT	PO	42.9				42.9
Mlalazi	28°57'S/31°48'E	Sub	PO			39.3	204.5	39.3
Kowie	33°36'S/26°54'E	wT	PO	35.2				35.2
Heuningnes	34°43'S/20°07'E	wT	PO	28.2				28.2
Gourits	34°21'S/21°53'E	wT	PO	21.1				21.1
Mthatha	31°57'S/29°10'E	Sub	PO			21.0	26.9	21.0
Tyolomnqa	33°14'S/27°35'E	wT	TO/C	3.7	10.5	15.7	30.2	19.4

ies did not have intertidal species such as the white mangrove *Avicennia marina* and the grass *Spartina maritima*. These estuaries lack intertidal salt-marsh and mangrove communities.

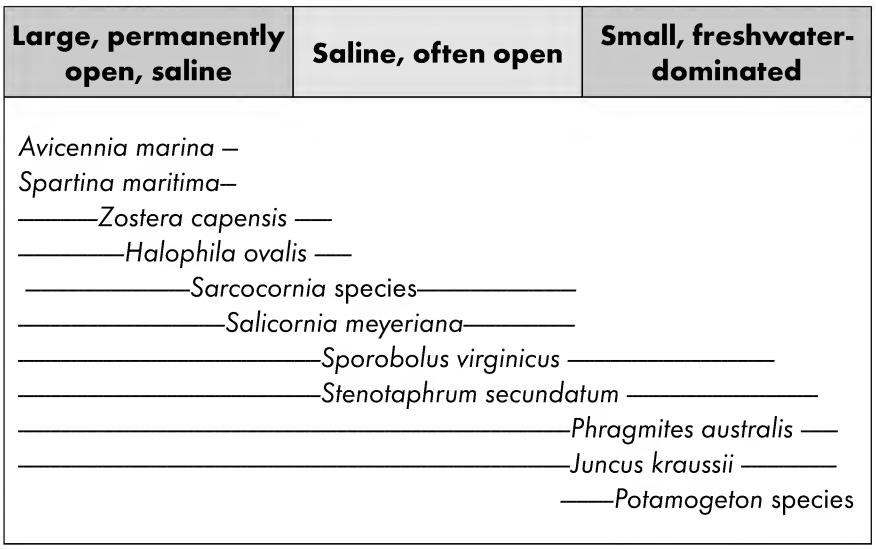

Figure 14.6 Conceptual scheme for the distribution of dominant macrophyte species across different estuary types. The position of the species in the chart indicates the estuarine type in which it is most dominant, while the line indicates the full extent of its range (modified after Walker 2004).

Plant Adaptations and Life Forms

Plants in salt marshes face challenges such as high and variable salinity, hypoxia and anoxia (albeit only temporary in some habitats), and unusually high concentrations of toxic compounds such as hydrogen sulphide or methane. Disturbance in the form of sudden surges of water rushing down the river beds after particularly heavy rains and associated increased sedimentation rates or man-made water pollution exacerbate the harsh saline environment. The response of the plants to these challenges are manifold and fascinating. Plants react to the lack of oxygen in subtidal and intertidal habitats usually by intricate mechanisms often involving regulation of gas transport, metabolic adaptations and changes in morphology mediated by hormones (e.g. Crawford 1982, 1992, Armstrong et al. 1994a).

In simple terms, plants tolerating the high concentrations of salt in the environment are usually called 'halophytes' (e.g. Flowers et al. 1977, 1986)—obligate or facultative, the former depending on whether the salt in high concentration is indispensable for optimal functioning of the organism. A high concentration of salt in the environment assists in the development of a plethora of ecomorphological and ecophysiological adaptations (e.g. Flowers et al. 1977, Ungar 1991), which obviously are not of monophyletic origin, yet they do show a certain relation to taxonomic categories. Several major 'physiotypes', based on specific patterns of ion uptake, have been recognised (Albert & Kinzel 1973, Albert 1982, Choo & Albert 1997).

The ecophysiological typological literature on halophytism (Steiner 1934, 1939, see also Albert 1982) recognises several types of strategies how plants cope with a surplus of salt: (1) The 'salt regulators' are able to restrict the dangerous increase of internal salt concentration either by desalination of their tissues through salt glands (*Limonium*) or through increase of succulence (many chenopods including *Sarcocornia, Salicornia, Chenolea, Suaeda* and vygies such as *Disphyma*). (2) The 'salt accumulators' are not able to prevent continuous increase of salt, but develop a series of mechanisms to remove the concentrated salt, for instance by shedding oversaturated tissues (*Plantago*). (3) The category of 'root filtrators' (the 'root excluding types' of Albert 1975) make use of root exclusion capacity of root membranes (Poaceae, e.g. *Puccinellia*). This mechanism, however, seems to be common in both halophytic and nonhalophytic grasses (see Albert 1975 for references).

Succulence (associated with osmotic compensation in old leaves) is a common phenomenon in halophytes and occurs throughout the taxonomic spectrum of plants in estuaries (Aizoaceae, Plantaginaceae, Asteraceae, Caryophyllaceae, Chenopodiaceae). In fact, interesting morphological convergences can be observed with regard to succulence, including a syndrome involving long, slender stems forming a tangle of short half-cylindrical to cylindrical (succulent) leaves. These syndromes include *Chenolea diffusa* and *Suaeda inflata* (both Chenopodiaceae), *Spergularia media* complex (Caryophyllaceae), *Poecilolepis* and *Cotula coronopifolia* (both Asteraceae). Saline environments are considered highly stressed (inductive only to limited growth), hence clonal growth (in the past often referred to as 'vegetative reproduction') should be of great importance to survival here. Indeed many dominant plants in South African estuaries show several modes of clonal growth involving nodal rooting of procumbent stems (*Sarcocornia*), above-ground parts or tillers and stolons (*Paspalum*, *Spartina, Stenotaphrum*), rhizomatous systems (*Halodule, Triglochin, Zostera*), and tillering typical of tussock graminoids such as *Puccinellia angusta* and *Juncus kraussii* (L. Mucina, unpublished data).

Uncertainty and harshness of the salt-marsh habitats are reflected not only in omnipresent clonality, but also by the presence of some annuals such as *Cotula filiformis*, *Salicornia meyeriana* and *S. pachystachys*, as well as by the occurrence of heterocarpy and the accumulation of permanent seed banks. Heterocarpy is known, for example, in *Spergularia* (Salisbury 1958, Telenius & Torstensson 1989) and in *Atriplex* (Khan & Ungar 1984)—both taxa with close relatives in South African salt marshes.

Community Structure and Dynamics

Regularity of the tidal regime, at least in permanently open estuaries, is the underlying factor controlling the formation of distinct vegetation zoning (e.g. Chapman 1974, Long & Mason 1983, Adam 1990) along a tidal elevation gradient including the distinct subtidal, intertidal and supratidal habitats (Figures 14.6 and 14.7). Local changes in microtopography can result in mosaics rather than distinct zonal bands. It has been suggested that several ecological factors, including abiotic environment filters and biotic interactions, control formation of zonation in salt marshes. Most important are tidal inundation frequency and hypoxia related to elevation of microsites (see for instance Olff et al. 1988, De Leeuw et al. 1993, Armstrong et al. 1994a, O'Callaghan 1994a–e, Sanchez et al. 1996, Mucina et al. 2003) together with the influence of biotic interactions such as competition (Pennings & Callaway 1992), grazing (Bakker & Ruyter 1981, Olff et al. 1997) and parasitism (Pennings & Callaway 1996, Callaway & Pennings 1998). In the past, facilitation received very little attention as a factor in structuring salt-marsh plant communities. Callaway (1994) has shown that shrubby *Arthrocnemum subterminale* (Chenopodiaceae) facilitated the

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Figure 14.7 Tidal salt-marsh zonation on the banks of the estuarine Bushmans River at Kenton-on-Sea (Eastern Cape). The lower zone is formed by a mixture of *Sarcocornia perennis* complex and *Salicornia meyeriana*, while the upper zone is dominated by *Chenolea diffusa* (all members of the Chenopodiaceae).

survival of several annuals in a Californian salt marsh, possibly through alteration of soil conditions such as mounding of soil under shrubs and lowering soil salinity under shrubs, hence creating favourable germination conditions. Callaway & Pennings (2000) reported on how several less competitive species can profit from the ability of *A. subterminale* to buffer the strong competitive effect of the perennial grass *Monanthochloe littoralis*. Leaking oxygen transported from leaves to roots through aerenchymous tissues of plants well adapted to hypoxia can enhance aeration of the substrate (soil oxygenation) and oxidation of iron, manganese and sulfide, hence ameliorating conditions for germination and survival rates in other associated plants in marsh communities (see Callaway 1995 for a review).

Generally low numbers of seeds have been found in salt-marsh zones (see for instance Leck 1989 and Ungar & Woodell 1993, Wolters & Bakker 2002 for references). Ungar & Woodell (1993) summarised the reasons for this paucity in terms of five possible factors including rapid germination, wash-out of seeds by tidal action, herbivory, inability of seeds to maintain dormancy, and parasitism. The major feature of the seed bank ecology in tidal salt marshes appears to be the differentiated correspondence between components of the above-ground vegetation and composition of the salt-marsh seed banks. Ungar & Woodell (1993) found a relatively high similarity between standing vegetation and seed banks in annual-dominated communities, while low similarities were found between vegetation dominated by perennials and the seed banks.

Very prohibitive ecological filters such as high salinity and hypoxia impose stress on the growth of plants. Decrease in species richness was observed with an increase of salinity (Garcia et al. 1993 for a salt-marsh profile, and Grillas et al. 1993 for a group of submerged macrophytes). The latter authors also found that higher species richness is associated with moderate values of above-ground biomass. The generally low species richness is exacerbated by the tendency of many salt-marsh dominants to use clonal growth as an effective strategy in the pre-emption of space.

Landscape-shaping Functions

Orson & Howes (1992) showed that salt marshes can remain stable for hundreds, even thousands of years. Temporal changes are most often associated with anthropogenic disturbance.

Salt marshes have a number of important functions that include sediment stabilisation, bank protection and filtering of sediment and pollutants. They are a source of primary production and provide a habitat and food for a variety of marine and estuarine species. They are essential inorganic and organic sources of nutrients for estuaries, although the degree of tidal flushing is important in determining how much of the nutrient is released to the water column (Childers & Day 1990). Salt marshes may make a disproportionately large contribution to the primary production of an estuary. For instance, although they cover only 38% of the area of the Kromme River Estuary, marsh plants contribute over 78% of the total primary productivity. However, less than 10% of this production enters the grazing food chain, the remainder being broken down to sediment detritus (Heymans & Baird 1995).

The conservation value of this vegetation lies in the fact that halophytes are the only plants adapted to grow in these harsh environments and the loss of this vegetation would lead to the formation of bare, dry salt pans that are more easily eroded by wind and water.

3.2 Terrestrial Habitats

Terrestrial coastal habitats are those which are not flooded (by sea or estuarine waters) for most part of the day. (Technically the supratidal terrace of a salt-marsh system is a terrestrial habitat too. However, we prefer it to be handled as a salt-marsh habitat.) Beaches, sand dunes and rocky headlands (coastal cliffs), supporting vegetation which does not show signs of tolerance towards prolonged flooding are the typical coastal terrestrial habitats. Although outside influence of tidal flooding, these habitats remain under direct influence of the sea through the deposition of salt spray and of fine air-borne sediments of sea origin.

According to the type of shoreline, Lubke et al. (1997) estimated that about 50% of the coastline is made of fine-grained sands and about 12% of coarse-grained sands, 19% of exposed rocky headlands, 17% of wave-cut rocky platforms, while pebbles/shingle beaches form less than 1% of the coastline.

3.2.1 Sandy Beaches and Dunes

About 70% of South Africa's 3 000 km long coastline is made up of sandy shores. They are extensive and contain many different types of habitats. Tinley (1985; see also Figure 14.8) has devoted much attention to describing coastal dune habitats and suggested a classification system for both coastal dunes (Tinley 1985, p. 17) and vegetation zones (Tinley 1985, p. 127–149) reflecting the age of the substrate, microtopography, and eventually also the stage of vegetation succession.

Below we shall use four pragmatic habitat zones on the sandy coasts, reflecting the position along landward gradients and age

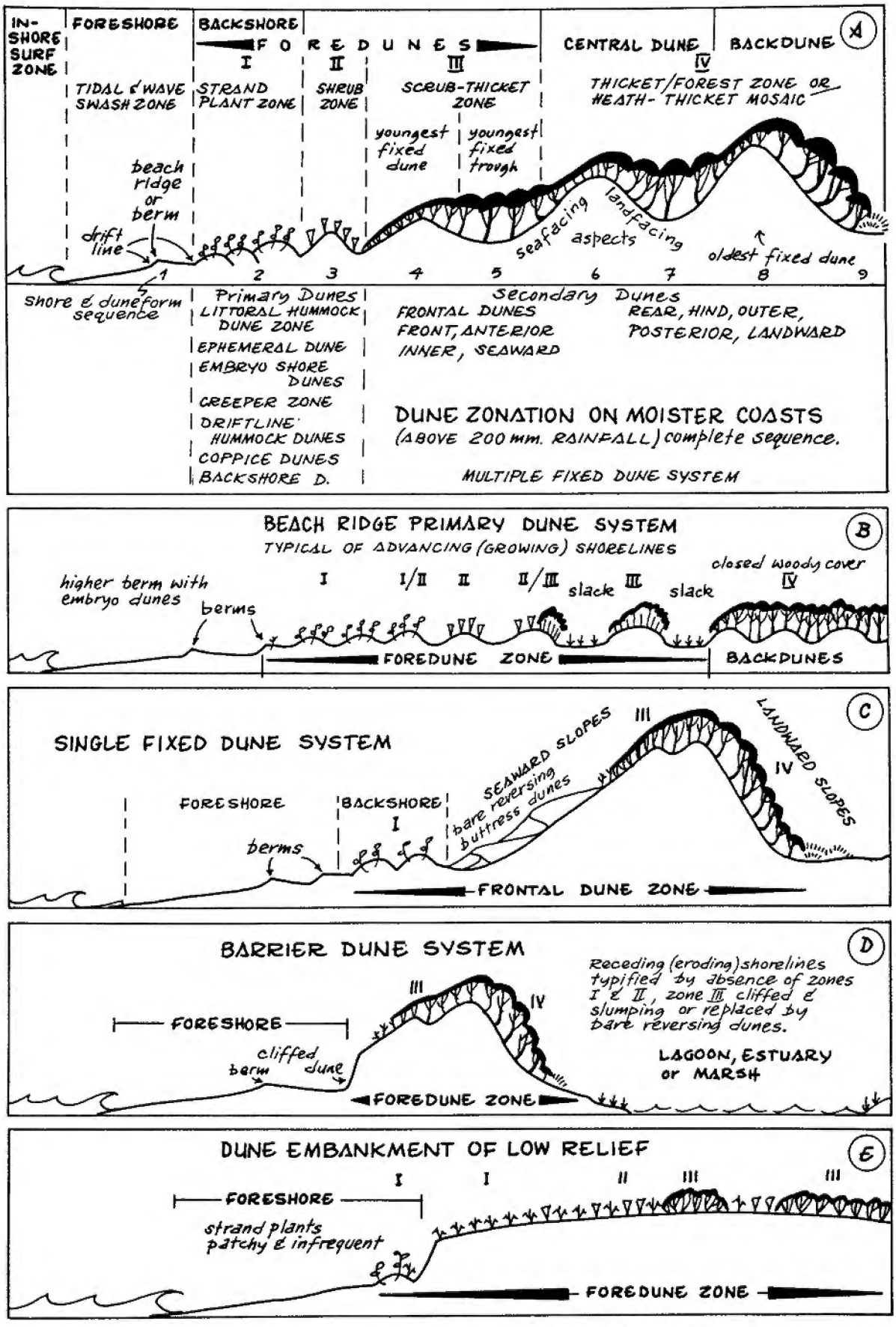

Fig 1 COAST DUNE NOMENCLATURE & VARIATIONS OF ZONATION SEQUENCES.

Figure 14.8 Coastal dune nomenclature and variations of zonation sequences (from Tinley 1985).

of the substrate. Our system includes: (1) sandy beaches (mostly 'vegetation-free'), (2) moving (young) foredunes, (3) stabilised (old) backdunes and (4) dune slacks.

Beaches

Sandy beaches dominate much of the shorelines of the seas of the world (McLachlan & Erasmus 1983, McLachlan 2000). They are unstable sea-borne sediments and debris at the direct sea/land interface—being reworked relentlessly by waves (at lower boundary) and wind (at upper boundary). Tinley (1985; see also Figure 14.8) calls this habitat 'foreshore'. Beaches are a very dynamic environment, constantly adjusting to erosion and accumulation forces in the littoral zone due to changes in wave regime and sidewash currents (Tinley 1985).

Pebble and shingle beaches are a rare phenomenon in South Africa, but shelly beaches, grading into true shell beds are common along the arid West Coast (Figure 14.9).

L. Mucina

Figure 14.9 Strandline formed by coastal shell bed and deposits of fragments of dead thalli of Cape kelp (*Ecklonia maxima*) on the coast at Betty's Bay (Western Cape). The vegetated zones in the foreground are formed by southern African coastal endemics such as *Tetragonia decumbens* (Aizoaceae) in the seaward zone and the grass *Thinopyrum distichum* in the inward zone.

The beach is a hostile environment for plants, hence beaches usually appear barren, without plant life. At the upper beach boundary, berms (beach ridges—unstable embryonic dunes) are formed which may support a few hardy 'pioneer' species such as *Arctotheca populifolia* and *Ehrharta villosa* var. *maxima* that are able to tolerate strong winds, high salt loads and rapid sand movement.

At the upper edge of the swash zone (just where the water surf would retreat back to the sea), much debris can accumulate. In regions where much dead material floats on the sea, this material often accumulates in the form of narrow belts of decaying debris on the beach, forming a special microhabitat called 'strandline' (Figure 14.10). High nutrient input ameliorates the soil conditions in these narrow zones, enabling some nutrient-demanding plant species (e.g. *Atriplex patula* subsp. *austroafricana, Tetragonia decumbens*) to establish. This coastal vegetation type has never been studied in South Africa. Its northern hemisphere analogue is known to syntaxonomy as the Cakiletea maritimae (see Mucina 1997).

Moving and young dunes

Coastal dunes form where sand is deposited onshore by the sea and at river mouths, or exposed by a dropping sea level as during the glacial. Dunes are piles of sand strongly variable in volume, shape (see Tinley 1985, p. 17 for a classification system), mobility (depending on age and vegetation cover and extent of root systems), and sometimes also in physical composition (depending on ratio of sand to other ingredients such as fine loamy particles, shells and other debris). As the accession of sand proceeds, the coastal dunes undergo development—they grow, accumulate humus particles, and finally become overgrown and stabilised by vegetation. Where conditions allow, zoned dune systems of progressing age are formed (see Figure 14.8 for various coastal dune patterns).

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Figure 14.10 Shell beds on the beach are a by-product of nutrient-rich upwelling coastal waters along the West Coast known for their high biomass productivity. Shown here is Mc Dougall's Bay, Port Nolloth (Northern Cape).

Dunes are (or have been) an integral part of an active littoral zone forming a single geomorphic unit, where sand is shifted between four compartments, including (1) beaches, (2) frontal dunes, (3) inshore or surf zone sand bars and banks, and (4) river mouths and estuaries (Tinley 1985). The link between these compartments is vital for the existence of an active dune system. Sandy sediments transported by rivers appear as the most important source of coastal sand as witnessed by increased accumulation of sand on coastal stretches near river mouths, especially those draining water basins with increased erosion activity. Much of the sand pre-destined to form coastal dunes is transported by so-called longshore (littoral) drift propelling the sediments along the southern African coasts northwards along the West Coast

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Figure 14.11 Salt-laden spray hovering over coastal dunes and strandveld thickets (in the background) of the Dune Park near Plettenberg Bay (Western Cape). The dominant creeping, succulent shrub covering the foredunes is *Tetragonia decumbens* (Aizoaceae).

and eastwards along the South and East Coasts. Past a specific point, the longshore transport is of the order 0.5 to 2 million m^3 per year (Heydorn & Tinley 1980, Tinley 1985). It has been estimated that about a third of the sand transported by the longshore drift is returned to land to form dunes (Compton 2004).

Dunes act as a natural sand reservoir for the replenishment of beaches during periods of erosion. They also serve as an important buffer zone between the sea and land, protecting coastal developments from flooding and wave damage. Vegetation is vital to this functioning as it helps to trap mobile sand, stabilising the dunes.

The dunes located closer to the beach or occurring on the upper boundary of the beach are called foredunes and they are 'young' in terms of their phase of development. The classic environmental factors and stresses associated with young dune environments include, salt spray, intense solar radiation (incident and reflected), high substrate mobility, abrasive substrate, low water-retaining capacity of the substrate, high wind speeds, large temperature fluctuations, high air and substrate temperatures, low concentration of macronutrients, and episodic over-wash and immersion (Barbour et al. 1985, Hesp 1991).

Due to the dynamic nature of the moving, hence young dunes, the vegetation occurring in these habitats has only a transient character and can disappear with a single storm event or change in response to changing environmental factors. The plants occurring in such unstable habitats are often called 'pioneers' as they are adapted to grow ahead of the accumulating sand, stabilising it so that other plant species can become established as the dune matures (Tinley 1985, Lubke & De Moor 1998) by building phytogenic hummocks, for which Hesp & McLachlan (2000) featuring aspects of ecology of South African coastal dunes, used the appropriate Arabic term *nabkha*. Near the sea, only a few pioneer plants withstand the salt spray (Figure 14.11), wind and unstable sand.

The microclimate, which is created by proximity to the sea, geomorphology, shading from other plants and the interaction with animals, also influences the vegetation locally. Each species has different adaptations to deal with these environmental stresses. While most species may tolerate sand burial, others may be stimulated by high accretion rates (*Ammophila arenaria*; see Knevel 2001). Salt spray contributes to the physiological desiccation of plants, and can also be responsible for zonation patterns (Donnelly & Pammenter 1983). In addition, dune plants often possess xeromorphic attributes. For example, leaf hairs (*Arctotheca populifolia*; Ripley et al. 1999), leaf succulence, waxy cuticles (*Scaevola plumieri*; Pammenter 1983), leaf rolling and sunken stomata (*Ammophila arenaria*; Peter 2000) are all traditionally associated with plants of dry environments. Yet there is little consensus as to whether it is a xeric environment, as there is still little information on the extent to which dune plants experience water stress (Peter 2000). Many species have extensive root systems and probably utilise the dune aquifer water (Peter & Ripley 2000), while others may utilise water in the superficial layers of sand resulting from precipitation, dew or fog (Barbour et al. 1985, Köpke 1988).

Old stabilised dunes

As the stabilisation of dunes progresses, primitive dune soils enriched by humus are formed, allowing establishment of shrubby vegetation which protects the dune (soil) surface from moving, desiccation, and removal of litter by wind, thus further enriching the soils.

On the established foredunes a little further inland, the pioneer species give way to coastal dune shrubland. Due to their generally dense cover, these shrublands have been termed 'thicket'. Where exposed to wind (and associated sand blasting during

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Figure 14.12 Alexandria Dune Field: One of the largest coastal seas of sand in the southern hemisphere (a view from Diaz Cross near Boknes westwards).

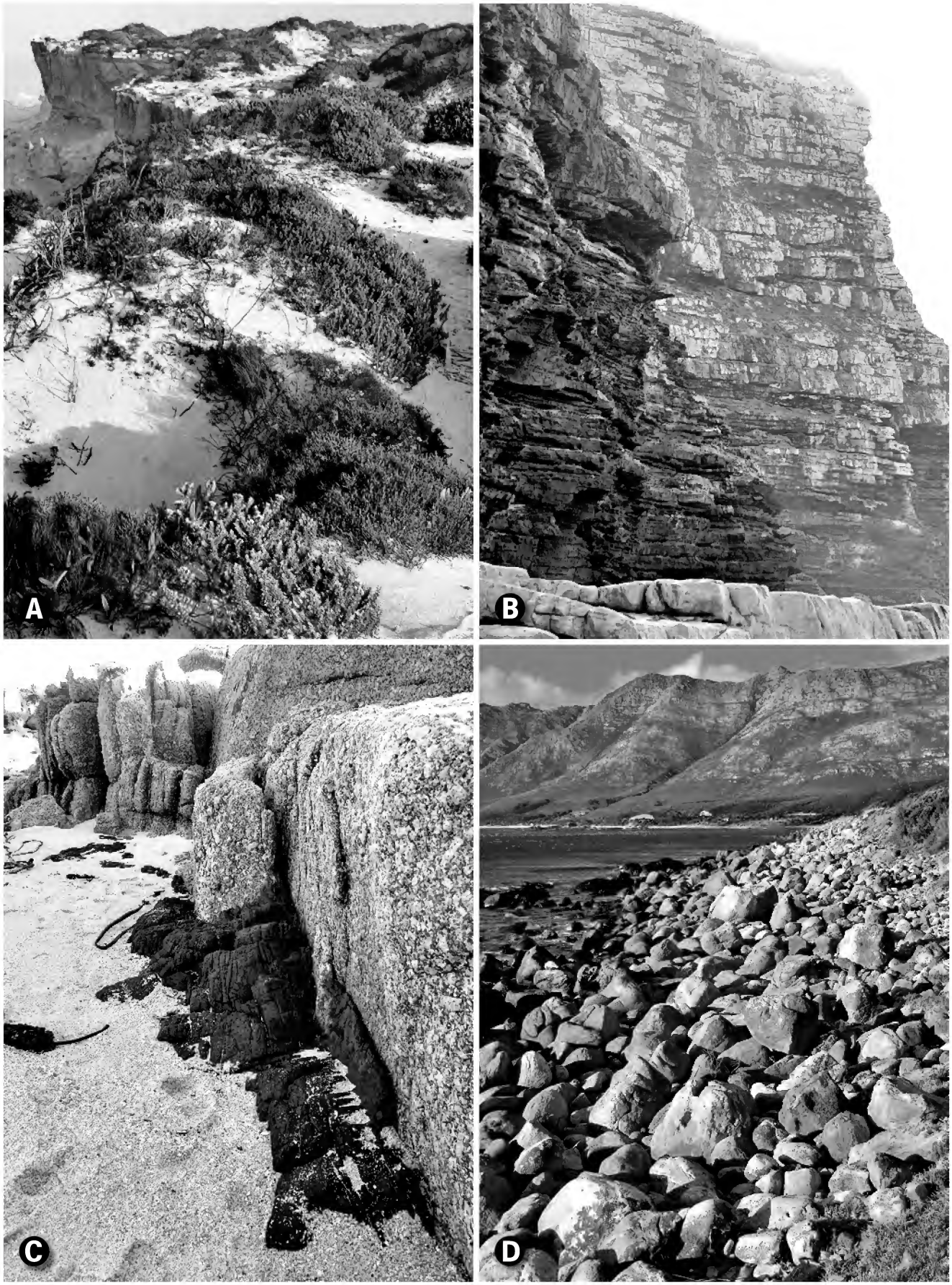

Figure 14.13 A: Miocene aeolinite coastal cliffs on Swartklip in the Wolvengat Nature Reserve near Khayelitsha (Cape Town). B: Coastal rocks built of Table Mountain Group sediments at Cape Point (Cape Peninsula), with typical TM sandstone in the upper layers and dark slates of the Graafwater Formation at the base. C: Cape granite coastal rocks with dolerite intrusions (dark rock) that penetrated the granite plutons at the time of the break-up of Gondwana. D: Large boulders of Cape shale on the stony beach of Kogelbaai near Rooiels in False Bay (Western Cape). Photographer: L. Mucina.

stormy weather) and frequent salt spray 'showers', the windward stands of the coastal thicket are low and 'wind-sheared' in places. Species such as *Morella cordifolia, Passerina rigida, Rhus crenata, Robsonodendron maritimum* and *Maytenus procumbens* as well as climbers such as *Cynanchum natalitium* and *Rhoicissus digitata* are typical of such habitats. On leeward slopes of the older dunes, tall thickets can develop; these are also found on the oldest and best stabilised dunes, sometimes deep inland. This vegetation consists of a dense community of dwarf(ed) trees and shrubs with a compact canopy flattened by wind pruning. Instead of a dense understorey, there is a thick layer of plant litter covering the sandy floor.

In areas of high rainfall and well-developed soils, dune thicket communities can develop on the oldest dunes (backdunes) furthest from the sea. In sheltered dune depressions in the south (Eastern Cape) and on the leeward slopes in general in a broad band in the north (KwaZulu-Natal), dune forests replace the dune thickets (see Von Maltitz et al. 2003 for detailed descriptions of these dune forests; see also Chapter 12 in this book).

In the low-rainfall areas—from De Hoop as far as Kenton-on-Sea—several dunefields are found (i.e. Alexandria Dunefield; Figure 14.12). They are built of relatively old dunes, but the foredunes remain largely unvegetated. Few plants are adapted to withstand these conditions of low rainfall, strong winds and mobile sand. However, deep within the dunefield isolated patches of (usually shrubby) vegetation called 'bushpockets' can be found (Talbot & Bate 1991). Bushpockets migrate with the dunes—the plants constantly extend their eastern borders while sand inundates their western borders. In this way they migrate with the dunes at a rate of around 2–3 m per year in an easterly direction (McGwynne & McLachlan 1992, Lubke & De Moor 1998).

Dune slacks

The complex dune systems (especially extensive dunefields) usually contain damp interdune depressions known as dune slacks. As the dune migrates, it exposes virgin sand that is colonised by salt-tolerant pioneer species. Here the groundwater, which is rich in nutrients, lies close to the surface as it flows towards the sea. Since root systems can reach down to the water table, plants in the slack are not limited by availability of water, as they are in other parts of the dune field. In turn they are limited by salt deposition (salt spray) and burial and abrasion by sand. Especially within large mobile dune systems on the south and east coast, dune slack communities are frequently found. However, on the KwaZulu-Natal coast, slack communities are often less frequent since more permanent plant communities rapidly establish in the dune hollows. Plants of dune slacks often share many characteristics with dune pioneer communities, for instance occurrence of species such as *Sporobolus virginicus* (south and east coasts) and *Cladoraphis cyperoides* (west coast). The role of dune slacks in vegetation succession within dune systems of the Eastern Cape is given in Lubke & Avis (1982a, b 1988, 2000) and McLachlan et al. (1987).

3.2.2 Rocky Shores: Coastal Cliffs and Headlands

Rocky substrates range from headlands with vertical cliffs to wide, wave-cut platforms or jumbles of boulders polished by the motion of the ocean. They differ from dune coasts in having stable substrates and shallow soils and variable geology. In False Bay alone, the coastal cliffs can be built of Proterozoic Malmesbury shales and Cape granite, Devonian Table Mountain sandstones, Jurassic dolerites, and finally Plio-Pleistocene calcium-rich aeolinites (Figure 14.13). High salt deposition (exposure to salt spray and seawater splash), extremely high insolation and high levels of UV radiation, nutrient input by birds, constant deposition and erosion of fine soil by relentless winds are ecologically critical. Along rocky headlands with exposed cliff faces salt spray is often a limiting factor to plant growth. Stormy weather in winter may reach higher elevated cliffs, forming temporary salty pools which desiccate and leave pockets of salt bloom (Figure 14.14). In the pockets of dune rocks the soil accumulated is nutrient-poor and often saturated with salt.

Rocky coasts are home to interesting stress-tolerant flora and vegetation. Consequently the vegetation is as species-poor as in much of the remainder of the coastal vegetation composed of plants able to tolerate extreme environmental stress. The combination of broadly distributed (salt-tolerant) generalists such as *Chenolea diffusa, Disphyma crassifolium* and *Tetragonia decumbens* and local endemics such as several taxa of *Limonium* (Plumbaginaceae), *Drosanthemum, Prenia* and *Ruschia* (Aizoaceae) and *Sarcocornia littorea* (Chenopodiaceae) adds to the uniqueness of the coastal rocky habitats. Where sand accumulates in pockets on the rocks, herbaceous communities similar to those of the young dunes can occur (Lubke & Van Wijk 1988, Taylor & Boucher 1993). Low coastal thickets often cover coastal cliffs, with a typically wind-sheared appearance (Figure 14.15) in windward positions. They often support shrubby succulents such as species of *Carpobrotus*, *Drosanthemum*, *Euphorbia* and *Tetragonia* (Avis 1992, Weisser & Cooper 1993, Lubke et al. 1997).

Firm ground of remote coastal cliffs and boulder beaches (usually on islands and exposed promontories) offer perfect resting and roosting habitats for colonies of marine birds, including southern African endemic Jackass penguins (*Sphaeniscus demersus*; Figure 14.16), cormorants (*Phalacrocorax* species), Cape gannets (*Sula capensis*), but also marine mammals such as fur seals (*Arctocephalus pusillus pusillus*) and rarely also Cape clawless otters (*Aonyx capensis*). The bird and seal colonies are responsible for large deposits of nutrients onto otherwise nutrient-poor rocky shores. They rework the sparse soil and create

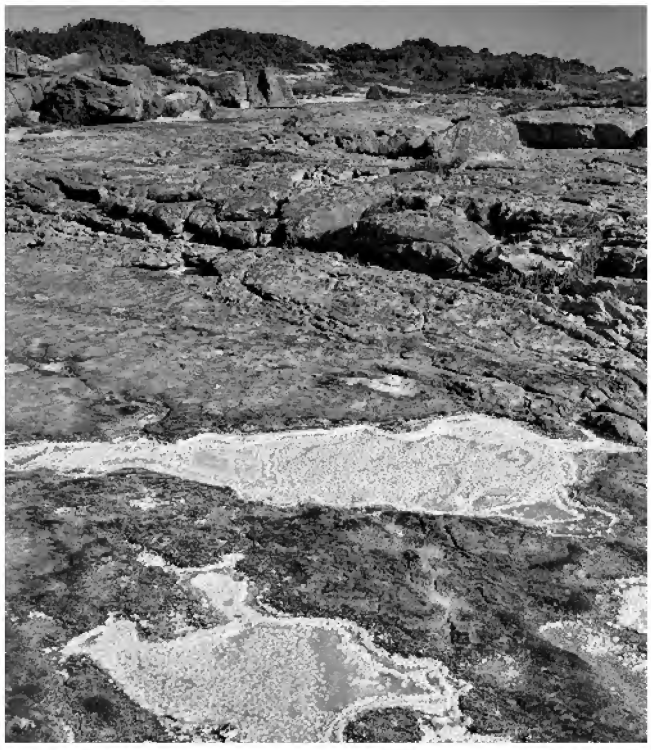

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Figure 14.14 The semi-arid West Coast (here near Elands Bay) is a stressed environment—salt bloom precipitated by repeated evaporation of sea surf in rock pools on coastal sandstone cliffs.

L. Mucina

Figure 14.15 Coastal granite cliffs and steep slopes near Herold's Bay near George (southern Cape) covered by wind-sheared coastal thicket.

new microhabitats. Marine animals are a vital part of the coastal ecosystem cycles and enjoy protection.

Vegetation of coastal rocky headlands is a neglected topic of vegetation ecology in southern Africa. Only a few accounts address this unique type of vegetation specifically (Ward 1980, pp. 25–28, 45, 46, Lubke 1983, Hoare et al. 2000).

West Coast would fall under the Benguela Province, with Cape Point as the southernmost border. The narrow coastal stretch between Cape Point and Cape Agulhas is called the Western Overlap, linking the (cold) temperate Benguela Province with the (warm) temperate Agulhas Province. The latter province then spans from Cape Agulhas as far as East London, where it gives way to the Eastern Overlap, which according to Bolton & Anderson (1997) reaches as far as Durban. However, as shown by Bolton et al. (2004), based on re-analysis of seaweed distribution data, this overlap should be extended as far north as the St Lucia estuary. The other tropical province, the Indo-Pacific Province, includes the marine waters offshore of Maputaland, along the South African Indian Ocean seaboard north of St Lucia. A different classification of the marine environments was suggested by Seagrief (1988), encompassing three zones (East Coast, South Coast and West Coast) and two overlaps, conceptually roughly corresponding to the scheme described above, but spatially different.

The recent classification of marine biozones (Lombard et al. 2004, Driver et al. 2005) recognises five 'intertidal biozones', addressing the estuaries in the first place. The system includes: (1) Namaqua Intertidal Biozone (mouth of Orange River to St Helena Bay), (2) Southwestern Cape Intertidal Biozone (St Helena Bay to Cape Point), (3) Agulhas Intertidal Biozone (Cape Point to Kei Mouth), (4) Natal Intertidal Biozone (Kei Mouth to St Lucia), and (5) Delagoa Intertidal Biozone (St Lucia to the Mozambique border). The above-mentioned sources also define biozones in purely marine environments, including shallow photic, deep photic, subphotic zones, upper and lower slope of continental shelf, and abyss.

On *terra firma* Tinley (1985) adopted a combination of rainfall regime, wind directions, coastal geomorphology and habitat complexity to coin his system of six coastal regions including the West Coast (Kunene River to Olifants River), South West Coast (Olifants River to Cape Agulhas), South Coast (Cape Agulhas to Cape St Francis), South East Coast (Cape St Francis to Kei River), Transkei Coast (Kei River to Mtamvuna River), and KwaZulu-Natal Coast (from the mouth of Mtamvuna northwards). The team of the National Biodiversity Assessment 2004 adopted the Tinley's classification in their marine biozone delimitation (Lombard et al. 2004, Driver et al. 2005) while each of the coastal regions became a 'Supratidal Biozone'. In this chapter

4. Biogeographical Patterns

4.1 Major Biogeographical Divisions

The current biogeographical classification of marine inshore environments of southern Africa recognises two tropical and two temperate marine provinces as well as a further two regions of overlap. The origins of this classification recognise the influence of sea currents (hence sea temperatures) on the distribution of marine fauna and flora (Stephenson 1939, 1944, 1948, Brown & Jarman 1978, Bolton et al. 2004). The Tropical West Africa Marine Province does not reach our region since its southernmost limit lies around the Kunene River mouth at the Namibian/Angolan border. The rest of the Namibian and South African

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Figure 14.16 Mixed colony of jackass penguins (*Spheniscus demersus*) and Cape cormorants (*Phalacrocorax capensis*) on coastal sandstone cliffs overlooking a cove filled with Cape kelp (*Ecklonia maxima*) at Stony Point, Betty's Bay (Western Cape).

Table 14.2 Coastal regions of South Africa (modified after Tinley 1985 and Lubke et al. 1997).

Coastal region	Coastal stretch	Main habitat types		Rainfall patterns	Wind directions
West Coast	Alexander Bay to Olifants River	fine-grained sandy beaches and shell beds	rarely rocky coast	erratic, but mostly in winter; coastal fog	S, SW
South West Coast	Olifants River to Cape Agulhas	fine-grained sandy beaches	exposed rocky headlands/ wavecut platforms	low, winter	SW, S/NW
South Coast	Cape Agulhas to Cape St Francis	wavecut rocky platforms	fine-grained sandy beaches	all seasons (more in winter in the western part)	SW, W, E
South East Coast	Cape St Francis to Kei River	fine-grained sandy beaches	wavecut rocky platforms	all seasons (mostly spring and autumn in the west and summer in the east)	SW, SE, E, NE
Wild Coast	Kei River to Mtamvuna River	wavecut rocky platforms	rarely coarse-grained sandy beaches	summer	SW, NE
KwaZulu-Natal Coast	Mtamvuna River to Mtunzini	coarse-grained sandy beaches	rarely exposed rocky headlands	summer	S, SE, NE
Maputaland Coast	Mtunzini to Mozambique	coarse-grained sandy beaches	rarely exposed rocky headlands	high, summer	S, SE, NE

we also follow the Tinley's (1985) classification except that we renamed the 'Transkei Coast' 'Wild Coast' and separated the tropical Maputaland Coast from the original 'KwaZulu-Natal Coast' of Tinley (1985) (Table 14.2).

4.2 Algal Beds

South Africa has 878 species of seaweeds described in the literature (J.J. Bolton, unpublished data), which is around 10% of the global total. The marine habitats are very varied, with three of the four major seaweed floras of Sub-Saharan Africa occurring in South Africa. The West Coast shares a flora of cool-temperate species with Namibia (Benguela Marine Province), which is rapidly replaced in southern Angola by tropical West African species. Between the Cape Peninsula and Cape Agulhas is a true overlap flora, with relatively equal numbers of West Coast and South Coast species. The South Coast (Agulhas Marine Province) has a distinct warm-temperate flora. From around Port Elizabeth eastwards, including most of KwaZulu-Natal, there is a gradual overlap of warm-temperate South Coast species being replaced by tropical species, which generally have wide distributions in the tropical Indo-West Pacific. In the extreme north of KwaZulu-Natal, in the region of St Lucia/Cape Vidal, there is a more rapid turnover of species. More than 70% of species in the extreme north (Maputaland) have tropical affinities. The major points of species changeover along the coastline are thus around the Cape Peninsula, around Cape Agulhas, and to a somewhat lesser extent St Lucia/Cape Vidal.

Almost 40% of South African species are endemic to temperate southern Africa. South African endemism is highest on the south coast, with most West Coast species also occurring in Namibia (Bolton 1999, Bolton & Stegenga 2002). South Coast endemism declines gradually from Port Alfred eastwards. The seaweeds of the East Coast are best described as an overlap flora, with very few species endemic to KwaZulu-Natal. The West Coast flora is relatively species-poor, with around 140–150 species recorded in each 50 km coastal section. At any one point, the South and East Coast floras are around twice as diverse, with around 270–330 species recorded in each coastal section. Throughout the region, around 60–70% of the species present at any one point are red algae (Rhodophyta). The West and South Coast floras have fairly equal numbers (15%) of each of the brown algae (Phaeophyceae) and green algae (Chlorophyta). Moving eastwards in KwaZulu-Natal, there is a slight increase in brown algae (to 17–18%), and a larger increase (to 25%) in green algae, as the flora becomes tropical.

The overwhelming factor determining large-scale, biogeographical ranges of seaweed species is seawater temperature regime. The cool-temperate flora of the West Coast is determined by major upwelling from the Benguela Current, with the range of monthly mean temperatures around 11–14°C. The northernmost section of the East Coast (Maputaland) is affected by the inshore flow of the tropical Agulhas Current, with monthly means of 23–29°C. In between, the South Coast has a generally wider range of monthly means at any one point (12–22°C), where eddies from the Agulhas Current and sporadic upwelling periodically affect conditions.

The upwelling of cool, nutrient-rich water on the West Coast supports large subtidal beds of kelps (*Ecklonia maxima* and *Laminaria pallida*: large brown algae of the Laminariales). There is very little grazing pressure in kelp beds on the West Coast proper, resulting in an abundant understorey of predominantly foliose red algae. East of Cape Point, sea urchin grazing results in extensive cover of coralline red crusts. Grazing by herbivorous fish gains in importance as an ecological factor moving eastwards. Biomass of fleshy and foliose intertidal species is also highest on the west coast, possibly due to a combination of higher nutrients and coastal fog which reduces desiccation during low tides. On the West Coast, much seaweed biomass is composed of Gigartinaceae (*Gigartina*, *Sarcothalia*, *Mazzaella*), while on the South and East coasts species of *Hypnea* are particularly abundant. On the South and East Coasts the subtidal zone is generally dominated by articulated coralline red algae (*Amphiroa*, *Arthrocardia*, *Cheilosporum* etc.), with large populations of siphonous green algae particularly in sandy gullies (especially species of *Caulerpa*, *Codium* and *Halimeda*). In Maputaland, communities assume a more tropical aspect, with many subdominant species, and many hard substrates covered with extremely diverse communities of small filamentous and foliose species, forming a low 'turf' due to grazing, particularly by herbivorous fish. The tropical seagrass *Thallasodendron cili-*

atum is also common in the Maputaland intertidal zone.

4.3 Estuaries

According to O'Callaghan (1994a) and Adams et al. (1999), all salt marshes (including intertidal and supratidal) in South Africa cover approximately 17 000 ha with 75% confined to the top five largest estuarine systems namely St Lucia, Berg, Olifants, Knysna and Langebaan (Table 14.1). Lake St Lucia (68 000 ha) is the largest estuary in South Africa, making up just over half of the country's estuarine area. The narrows of St Lucia estuary are tidal when the mouth is open. Salt-marsh plants are found on fringes of the mangroves. Stands of *Juncus kraussii* occur in sites less frequently flooded. The dominant plants are the grasses *Sporobolus virginicus* and *Paspalum vaginatum* as well as the succulents *Sarcocornia natalensis* complex and *Salicornia meyeriana*. These plants also occur on the western shoreline of the estuary and along the False Bay shoreline where there is no significant inflow of groundwater. Salt marshes also occur on the floodplains of the rivers entering False Bay as well as on the islands, the peninsulas and along those parts of the eastern shoreline where the estuary edge topography acts as a barrier preventing inflow of surface water (Taylor et al. 2006). Although tidal influence does not occur in these areas, the wet/dry cycles and wind cause large fluctuations in salinity and water level.

The data in Table 14.1 indicate that the estuary with the second largest salt-marsh area in the country is that of the Berg River. The value for the supratidal salt marsh is possibly an over-estimation as it probably includes the large floodplain wetlands that are brackish and mostly characterised by reeds and sedges. A recent mapping exercise for the Olifants estuary indicated the extensive supratidal and floodplain areas where a single species, *Sarcocornia pillansii*, is dominant (Adams et al. 2005). According to Maree (2000) the intertidal wetlands of Knysna cover an area of 1 000 ha. This includes 355 ha of the submerged aquatic *Zostera capensis*. The intertidal salt marsh around George Rex Drive and Thesen Island covers 170 ha and around Brenton-on-Lake 314 ha. The supratidal salt marsh is not as extensive and covers approximately 60 ha. The marshes in the upper reaches of the estuary cover 150 ha and consist mostly of *Juncus kraussii*.

Due to the high rainfall and brackish nature of the temporarily open/closed estuaries in KwaZulu-Natal, salt marsh

	M	K	T	E	S	C	W	Distribution Limit	
ZONE I									
Cyperus crassipes	■							Cape St Lucia	S
Scaevola sericea	■							Kosi Bay	S
Canavalia rosea	■	■	■	■				Kei Mouth	W
Launaea sarmentosa	■	■	■	■				Coega (PE)	W
Phylohydrax carnosa	■	■	■	■	■			Plettenberg Bay	W
Ipomoea pes-caprae	■	■	■	■	■			Knysna	W
Gazania rigens var. uniflora	■	■	■	■	■			Mossel Bay	W
Scaevola plumieri	■	■	■	■	■	■		Arniston	W
Arctotheca populifolia	■	■	■	■	■	■	■		
Dasispermum suffruticosum		■	■	■	■	■		Durban	E
Ehrharta villosa var. maxima			■	■	■	■		Port Edward	E
Tetragonia decumbens			■	■	■	■	■	Port St Johns	E
Hebenstretia cordata**				■	■	■	■	Kei Mouth	E
Senecio litorosus				■	■			Great Fish River	E
Gazania rigens var. leucolaena				■	■	■		Coega (PE)	E
Thinopyrum distichum				■	■	■		Kei Mouth	E
Senecio elegans				■	■	■		Tolora Mouth	E
Silene crassifolia				■	■	■		Port Alfred	E
Carpobrotus acinaciformis				■	■	■		Port Elizabeth	E
Eragrostis sabulosa					■	■		Still Bay	E
Senecio maritimus					■	■		Still Bay	E
Oncosiphon sabulosum					■	■	■	De Hoop	E
Trachyandra divaricatum					■	■	■	Plettenberg Bay	E
Didelta carnosa var. tomentosa**					■	■	■	De Mond	E
Cladoraphis cyperoides**						■	■	Macassar	E
Manulea tomentosa						■	■	Pearly Beach	E
ZONE II									
Guettarda speciosa	■							Black Rock	S
Sophora inhambanensis	■							Sodwana Bay	S
Tephrosia purpurea subsp. canescens	■	■						Hibberdene	S
Stipagrostis zeyheri subsp. barbata	■	■		■	■			Plettenberg Bay	W
Carpobrotus dimidiatus	■	■	■	■	■			Boknes	W
Passerina rigida	■	■	■	■	■	■		Rooiels	W
Chrysanthemoides monilifera*	■	■	■	■	■	■	■	Brandsebaai	N
Metalasia muricata			■	■	■	■		Nxaxo Mouth	E
Morella cordifolia				■	■	■		Kei Mouth	E
Psoralea repens				■	■	■		Kenton-on-Sea	E
Passerina paleacea					■	■		Still Bay	E
Passerina corymbosa				■	■	■		East London	E
Phylica littoralis					■	■		East London	E

Figure 14.17 Geographical distribution of two groups of coastal plant taxa typical of Zone I and Zone II (according to Tinley 1985). For the delimitation and characteristics of the Coastal Regions see Table 14.4. M: Maputaland Coast, K: KwaZulu-Natal Coast, T: Wild Coast, E: South East Coast, S: South Coast, C: South West Coast, W: West Coast. The shaded area indicates the occurrence of a taxon in a given Coastal Region. Sources of the distribution of the taxa: Tinley (1985), Pooley (1998), Goldblatt & Manning (2000), PRECIS database, L. Mucina (unpublished data). Two subspecies of *Chrysanthemoides monilifera** appear to prefer coastal habitats: *C. monilifera* subsp. *rotundata* is characteristic for the eastern coasts (M, K), while *C. monilifera* subsp. *pisiformis* typically occurs along the western and southwestern coasts (W, C, S). The meeting zone of these two subspecies is possibly Coastal Region E, but due to taxonomic (identification) problems this remains open to further investigation. **Of the West Coast species, the ones indicated by double asterisk reach as far north as AZd 1 Namib Seashore Vegetation unit.

is mostly absent (despite the largest area of salt marsh in the country being in St Lucia estuary). Hygrophilous grasses (e.g. *Sporobolus virginicus, Paspalum notatum* and *Cynodon dactylon*) are, however, common.

South African estuaries occur within three biogeographical zones, the cool-temperate zone on the West Coast, the warm-temperate zone that extends from about Cape Point to the Mbashe estuary in the Eastern Cape and the subtropical zone on the East Coast (Table 14.2). In the subtropical zone, mangroves tend to replace intertidal salt marsh. Colloty et al. (2002) found that in permanently open estuaries, mangroves occurred north of the Great Kei estuary and swamp forest north of the Mngazana estuary. In temporarily open/closed estuaries swamp forest, reed and sedge beds occurred north of the Mngazana estuary where they replaced the salt marsh. However, in some estuaries all three habitat complexes were present and thus the East Coast transitional area has a high biodiversity. Species distribution was associated with the increase in rainfall northwards.

Reeds and sedges are the dominant macrophytes in temporarily open/closed estuaries throughout the country. In the subtropical KwaZulu-Natal Province, rooted submerged macrophytes are rare in these estuaries. This has been attributed to an increase in catchment and bank erosion, sediment deposits and a lack of available light. Steeper gradients and greater water velocities during rainfall events also disturb sediments and remove these macrophytes (Perissinotto et al. 2004). Many of the Eastern Cape estuaries (e.g. Seekoei and Kabeljous) have extensive submerged macrophyte beds consisting of both *Ruppia cirrhosa* and *Zostera capensis*. During the closed phase, extensive blooms of filamentous green macroalgae can occur.

4.4 Dunes

The South Africa coastline is diverse, with a wide variety of habitats stretching over an area which is transitional between winter- and summer-rainfall climates (Avis 1992), corresponding to the distribution of one or more biomes in the hinterland and to one or more patterns of the sea currents (Table 14.3). The distribution of particular species (for a selection see Figure 14.17) shows clear patterns of diminishing importance of the coastal tropical element in a westward direction and increased endemism towards the Cape coasts. Several important regional discontinuities in species distributions have been identified (e.g. East London–Kei Mouth interval) and incorporated into the definition of our vegetation units (for more details see below), while some of the other discontinuities (such as co-occurrence of western limits of distribution in some species around Still Bay and Plettenberg Bay) are still awaiting explanation. One of the approaches to the question of distribution of plants along the coast was to seek ecophysiological explanations, such as demonstrated for *Scaevola plumieri* by Peter & Ripley (Peter 2000, Peter & Ripley 2000, Ripley 2001, Peter et al. 2003).

The West Coast of southern Africa, north of Cape Columbine, has a mixture of dry-coast elements and taxa recruited from the generic pools of the neighbouring semidesert biomes (Aizoaceae) and Cape elements (Tinley 1985, Lubke & Van Wijk 1988, Lubke et al. 1997). The vegetation of the southern coasts is dominated by elements of the Cape flora and it has a considerable coastal endemism. All the floras listed above interact in a complex manner along the southeast coasts of the Eastern Cape (Lubke & Van Wijk 1988). The East Coast is strongly influenced by (sub)tropical elements and some links to afrotemperate woody flora (Lubke & Van Wijk 1988) as well as to distant Madagascar (Tinley 1985, Venter & Scott 1999, Venter 2000). Several coastal species have subcosmopolitan or wide (sub)tropical distribution (*Canavalia rosea, Ipomoea pes-caprae*, *Sporobolus virginicus*), pointing to the many common features of sand-coast ecology and the ability for long-distance dispersal of coastal flora.

5. Principles of Delimitation of Vegetation Units

The classification system of vegetation units as presented in this chapter is a synthetic product of habitat and biogeographical subdivisions of the coast (and adjacent sea waters) of South Africa.

Four groups of the coastal vegetation have been recognised (see Figure 14.18 for schematic distribution of the mapped patches):

(a) Coastal macroalgal beds.

(b) Estuarine salt marshes (Figure 14.14).

(c) Seashore (or strand) vegetation (including vegetation of habitats under immediate and current influence of the sea—beaches, coastal cliffs, coastal dunes).

(d) Azonal/intrazonal strandvelds.

5.1 Algal Beds

Within this category we include only two alga-dominated vegetation units of notable spatial extent—the Cape Kelp Beds (unit AZm 1) described in this chapter (see below), and AZm 2 Subantarctic Kelp Beds from the islands of Marion and Prince Edward, described in Chapter 15. Both units occur in the form of relatively small patches not shown on our Map. However, the inventory of extant patches of the Cape Kelp Beds is in progress (R.J. Anderson, personal communication) and mapping of the Subantarctic Kelp Beds remains a challenge for the future. Satellite imagery combined with 'sea-truthing' should generate the desired data for possible future editions of our Map.

5.2 Estuarine Vegetation

Three units were recognised and mapped within this group. AZe 1 Arid Estuarine Salt Marshes are ecologically and floristically very different from the other two units: in fact, the 'arid-climate' estuaries are more reminiscent of the concept of *sabkha* known to the Arabic-speaking world. In South Africa, these habitats are in many respects more saltwater-soaked flats on head-bays in poorly drained coastal lagoons straddling 'desert' and the sea, than true tidal salt marshes. The freshwater component is either negligible (due to the often intermittent nature of the rivers) or missing altogether. The salt-marsh/*sabkha* complex in the mouth of the Orange (Gariep) River is the most typical example in South Africa, while the salt flats on bays around Lüderitz (Namibia) are probably the best example of such an arid 'estuarine' (or rather *sabkha*) habitat on the southwestern desert coasts of Africa. The estuaries of AZe 1 are embedded within the Desert and Succulent Karoo Biomes.

The Cape estuaries (AZe 2) are typical of the warm-temperate climate region of the Cape Floristic Region (cold-temperate and warm-temperate marine temperatures). These estuaries range from brackish to hypersaline environments. Due to the small-scale nature of the estuarine habitat mosaic we have not mapped (at our working scales) the sublittoral, littoral and supralittoral habitats as separate units, although we appreciate the considerable ecological differences between these. Naturally, these habitats and constituent communities are mappable at larger scales as shown by a series of detailed maps of the Cape

estuaries in the CSIR inventory reports (see References). The separation of the subtropical AZe 3 unit was motivated by the general impoverished character of the salt-marsh flora and vegetation complexes, recognising that salt marshes are a phenomenon typical of extratropical regions. The zonal hinterland of the subtropical estuaries in South Africa is formed by the Indian Ocean Coastal Belt. Mangroves are an important element of the (sub)tropical estuaries. The mangroves are treated as a separate vegetation unit (FOa 3) in Chapter 12. Capturing the subtropical estuarine salt marshes has been a problem due to a lack of proper coverage. Therefore the largest patch of the AZe 3 unit (St Lucia) has not been distinguished from the lagoon proper at this stage.

Admittedly not all known estuaries (see Whitfield 1995, 2000 and Colloty et al. 2001 for exhaustive lists of the South African estuaries) are contained in our Map, both due to lack of mapping coverage of acceptable quality as well as the small scale of many of the salt-marsh patches. Larger estuaries open to the sea have not been distinguished from the sea on the Map.

5.3 *Dry Seashore Vegetation*

The delimitation of the seashore units follows the same principle as that of the estuarine (or 'wet seashore') units, except that the arid seashore is subdivided into AZd 1 Namib Seashore Vegetation and AZd 2 Namaqualand Seashore Vegetation. The former unit follows the part of the coast of one of the oldest and most arid deserts of the world—the Namib Desert. This hyperarid coastal vegetation extends to South Africa only marginally, and reaches its southernmost distribution limit on the Holgat River—the limit of a group of species identified as 'Namib intrusion' by Boucher & Le Roux (1993). The AZd 3 Cape Seashore Vegetation and AZd 4 Subtropical Seashore Vegetation represent warm-temperate versus subtropical coastal vegetation units. The major vegetation turnover appears roughly within the coastal interval spanning the mouth of the Buffalo River (East London) and Kei Mouth—in the region where Albany Thicket gives way to Indian Ocean Coastal Belt in the oceanic hinterland.

The dry seashore vegetation fringes the coast of South Africa in the form of an almost continuous belt, being interrupted only by the estuaries. Still it was technically infeasible to depict this belt on our Map in its entirety due to scale problems. In places it therefore happens that the strandveld units, both the intrazonal strandvelds classified within the Succulent Karoo and Fynbos Biomes (the latter summarised as Western Strandveld) as well as the azonal Eastern Strandveld (see below), become the coast-fringing vegetation on our Map.

The principles of the spatial and conceptual distinction between the coastal (seashore) vegetation and the hinterland strandveld units are discussed in Chapter 4 (Fynbos Biome) in this book.

5.4 *Eastern Strandveld*

The Eastern Strandveld units cover a large, about 1 000 km long, stretch of the East Coast, following the seaboards of the Indian Ocean. The vegetation units are well differentiated in climatic

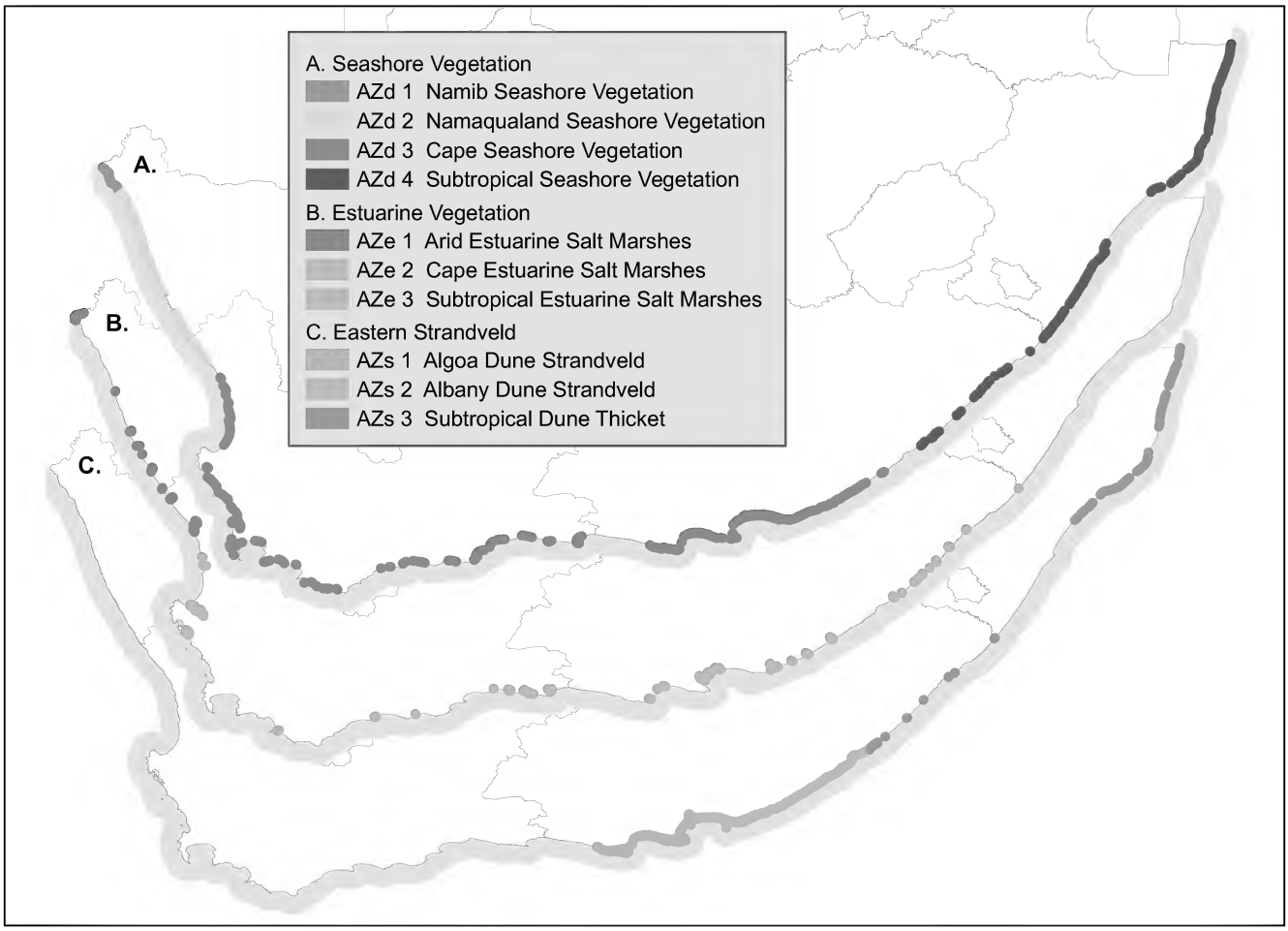

Figure 14.18 Distribution of coastal vegetation units along the South African seaboards. A: Seashore Vegetation, B: Estuarine Vegetation, C: Eastern Strandveld.

Table 14.3 Correspondence between biomes (as defined in this book), marine provinces and overlap (according to Bolton & Anderson 1997, modified by Bolton et al. 2004), and vegetation units of coastal affiliation, such as intrazonal and azonal strandveld units, seashore vegetation and estuarine salt-marsh units.

Biomes	Strandveld units	Seashore vegetation	Estuarine salt-marshes	Marine province or overlap
Desert	Dn 1	AZd 1	AZe 1	Benguela Province
Succulent Karoo	SKs 1, SKs 7, SKs 8	AZd 1, AZd 2	Aze 1	Benguela Province
Fynbos	FS 1–9, AZs 1	AZd 3	AZe 2	Benguela Province Western Overlap Agulhas Province
Afrotemperate Forest	FS 9	AZd 3		Agulhas Province
Albany Thicket	AZs 1, AZs 2	AZd 3	AZe 2	Agulhas Province Eastern Overlap
Indian Ocean Coastal Belt	AZs 3	AZd 4	AZe 3	Eastern Overlap Indo-West Pacific Province

terms, spanning a gradient of increasing precipitation (from 680 mm in Algoa Strandveld to over 1 000 mm in Subtropical Thicket) and temperature (MAT: 17.2°C, 18.0°C and 20.0°C). The delimitation between two units occurring in Albany Thicket (Algoa and Albany Strandvelds) follows Vlok et al. (2003). Much of the Subtropical Thicket has not been mapped due to scale problems—the patches of this vegetation occur as very narrow bands (often only several tens of metres) in KwaZulu-Natal, while in the Eastern Cape (along the Wild Coast) this type is rare due to specific coastal geomorphology (steep coastal cliffs), and it is limited to only small pockets on dunes in river mouths.

6. Conservation Challenges: Status, Threats and Actions

6.1 *Algal Beds*

South Africa has a seaweed industry that is based on the commercial collection of kelps and the red seaweeds *Gelidium* and *Gracilaria*, as well as the cultivation of *Gracilaria* and the green seaweed *Ulva* for abalone feed. Although the industry is relatively small compared to major producers such as Chile, it is worth about R25 million annually, provides hundreds of jobs and is viable and sustainable.

The mainstay of the local industry is the extensive beds of kelp (*Ecklonia maxima* and *Laminaria pallida*) that grow in the cool-temperate waters from Cape Agulhas up the West Coast and into Namibia. Beach-cast kelp has been collected, dried, milled and exported for almost 50 years for the production of alginate, a colloid with many industrial uses such as in dyes and paints. An extract from *E. maxima*, marketed as Kelpak®, is used locally and exported to over 30 countries where it is highly effective as a plant-growth stimulant in agriculture and horticulture. In the last decade, the huge increase in the farming of abalone in tanks has created a local industry based on harvesting and supplying fresh *E. maxima* fronds as feed for these valuable molluscs. More than 5 000 tons of fresh kelp fronds are currently cut for abalone feed per annum.

The red alga *Gracilaria gracilis* is collected from periodic wash-ups at Saldanha Bay on the west coast. The material is dried, sorted and exported for the extraction of agar, a colloid with wide uses in food and pharmaceutical products. Good-quality agars are obtained from the three *Gelidium* species that are harvested from shores in the warm-temperate waters of the Eastern Cape. *Gelidium pristoides*, a strictly intertidal species, is the most valuable on account of the high gel strength of its agar. *G. abbottiorum* and *G. pteridifolium* are found lower on the shore and in pools and gulleys, and fetch a slightly lower price. Teams of pickers cut the tops off the *Gelidium* plants, leaving the basal fronds to regenerate. Research has shown that the plants re-grow rapidly, and that harvesting has minimal ecological effects on the environment.

Seaweed harvesting is managed by the national Department of Environmental Affairs and Tourism on the basis of scientific research that is largely funded by the cost of commercial and recreational permits. The coastline is divided into 23 Concession Areas, and the rights to harvest a particular species in each area can be applied for periodically.

Several abalone farms cultivate quantities of seaweed (*Ulva* and *Gracilaria*) as abalone feed, particularly in the Eastern Cape, where there are no large supplies of feed in the form of kelp beds. One farm currently grows 3 tons of *Ulva* per working day in a series of 30 m long shallow ponds, with water movement provided by large paddle wheels. Even in the Western Cape, some farms are now growing their own *Ulva* and *Gracilaria* as a supplement to kelp, and ongoing research assists them to improve their cultivation methods. Ultimately, the goal is to integrate the farming of seaweed and abalone, so that feed is produced while the seaweeds remove inorganic nutrients from the abalone effluent, thus cleaning it for re-circulation within the farm.

6.2 *Estuaries*

Salt marshes have experienced a long history of destruction and alteration by human activities. Filling, dredging, ditching, impounding and draining as well as pollution have greatly reduced the total area throughout the world.

Reduction in freshwater input due to freshwater withdrawal from the estuary catchment results in an increase in salinity and loss of the species preferring brackish habitats (e.g. *Juncus kraussii*, *Cotula coronopifolia*). Freshwater reduction can also reduce the frequency and duration of open mouth conditions in temporarily open/closed estuaries. This can lead to the loss of intertidal species such as *Sarcocornia perennis* complex and

Spartina maritima. Prolonged closed mouth conditions and an increase in water level can lead to the loss of those species sensitive to submerged conditions. Too much freshwater may eliminate the salt-marsh community. O'Callaghan (1990b) has shown how poorly developed the halophytic vegetation in the False Bay estuaries is because of human impact and reduced saline input. He identified restriction in tidal input as a serious threat to Western Cape salt marshes.

Threats to seagrass, *Zostera capensis*, include bait digging and boating activities. Catchment degradation, erosion and an increase in sediment load results in smothering and a decrease in light available to these plants. *Z. capensis* has been lost from the Mthatha estuary and some KwaZulu-Natal estuaries due to an increase in sediment load.

The most common impact in supratidal salt marshes is encroachment by invasive plants followed by trampling and formation of footpaths constituting probably the most common impact affecting intertidal salt marshes (Coetzee et al. 1997). Water-saturated low marsh sediments and associated plants are highly susceptible to trampling and recover slowly. In the Knysna estuary, Maree (2000) found that the construction of roads, bridges and commercial developments often results in an increase in elevation, with the resultant establishment of terrestrial or alien species. Threats in the more rural areas of the former Ciskei and Transkei include agriculture and grazing. In estuaries closer to city centres or holiday resorts, encroachment by developments is the major threat. In the Swartkops estuary, 35 ha of supratidal salt marsh has been lost due to bridges, roads and other developments and 50 ha of intertidal marsh has been lost due to the development of Swartkops and Redhouse villages, salt works and roads (Colloty et al. 2000).

Intertidal salt marshes occur in the large permanently open estuaries. Only 18% of South African estuaries are permanently open and their status is threatened due to reduced freshwater input. An assessment of the habitat integrity of South African estuaries (Colloty 2000) showed that 'pristine' estuaries were mostly found in the former Ciskei and Transkei regions. Decreases in plant cover in the Transkei estuaries were mostly due to removal for agriculture or utilisation of wood in the case of mangroves. In the Ciskei, the estuaries that had the lowest habitat integrity scores, were those where plant cover was lost due to road construction at or near the mouth, e.g. Bira, Mpkeweni. In Cape and KwaZulu-Natal estuaries, residential and industrial developments have removed areas of estuarine habitat.

The National Spatial Biodiversity Assessment (Turpie 2004a, b, Driver et al. 2005) has identified estuaries that are critically endangered, vulnerable and least threatened. Permanently open estuaries in the cool-temperate and warm-temperate regions, which generally have the largest salt-marsh areas, were identified as endangered. The few large estuaries on the West Coast (Orange, Olifants, Berg) are under great pressure as they are each linked to a major river system and a large catchment that is heavily utilised, particularly for abstraction of freshwater.

Whitfield (2000) reported that 62% of South Africa's estuaries were in good or excellent condition, but the healthy estuaries were not evenly distributed among 13 different groups as defined by Turpie (2004b, see also Driver et al. 2005), based on climate zone and five basic types (including estuarine bays, permanently open estuaries, river mouths, estuarine lakes and temporary closed estuaries). There are 259 estuaries in South Africa (Turpie 2004b, Driver et al. 2005), but only a small fraction enjoys formal protection—14 enjoy high levels of protection and a further 27 have medium and low levels of protection. Estuaries that currently enjoy some protection status and have salt marsh present and are listed as Ramsar sites include the Orange River mouth, Heuningnes, Swartvlei as well as the World Heritage Site of the Greater St Lucia Wetland Park which includes two further Ramsar sites—St Lucia Estuary and Kosi Bay. Knysna is a partially protected estuary under jurisdiction of South African National Parks. A large portion of salt marsh is protected in the Langebaan Lagoon, part of the West Coast National Park.

A recent paper by Turpie et al. (2002) indicates the 32 estuaries in South Africa that should be included in a protected area network to ensure biodiversity conservation of all biota. The six estuaries with the largest intertidal salt-marsh areas in the country are included in this list. Intertidal salt marsh can be considered rare in South Africa because very few estuaries remain permanently open to the sea. The government must recognise salt marshes as a valuable national asset. There should be no further loss of marsh due to development or human interference. This can be easily monitored from aerial photographs.

Three major priorities for action have been identified by the National Spatial Biodiversity Assessment, namely (1) determine, implement and monitor the freshwater reserve for priority estuaries, (2) expand the number of protected estuaries, and (3) integrate resource management and land use planning in estuarine systems (Turpie 2004b, Driver et al. 2005). Guidelines for a strategy for the protection of estuarine biodiversity have been proposed by Turpie (2004a).

6.3 Beaches, Dunes and Strandveld

Coastal conservation areas play an important role in protecting the biodiversity of the coastal habitats and maintaining a coastal corridor for the movement of coastal fauna.

It is apparent that the coastal dune systems are diverse, vulnerable and variable environments. They are often multifunctional systems of great importance to society, and people are attracted to the coast for a number of reasons—aesthetic appreciation, recreation, harvesting of marine life, transport, a place to live, work or play, or for tourism. Hence, the coast has become a centre for economic activity and the increased pressure has many kinds of consequences on the (local) beach and dune environment.

On the West/Southwest coasts the main pressure comes from the human population (i.e. through fisheries, harbours, tourism/recreation) and the mining of heavy metals and diamonds (Boucher & Le Roux 1993). Along the South/Southeast coasts, mining activities are few, but coastal resorts are plentiful and subjected to intensive development (see for instance Taylor & Boucher 1993). Nearly 90% of the 6 million people of the Western Cape Province live in this area. The (smaller) coastal towns and resorts experience a seasonal influx of holiday makers, resulting in seasonal exacerbation of the impact of recreational development on the natural coastal ecology. Intensive tourism—an economic boost to most of the coastal regions—also has some negative facets such as direct damage to sensitive dune vegetation, especially during the holiday season (trampling), the spread of alien vegetation, sand starvation of certain beaches (i.e. Cape St Francis), pollution associated with urban development, building of excessive road networks and the like.

Further east, along the Transkei/KwaZulu-Natal coast (East Coast), human settlements can be found that date back centuries (Weisser & Cooper 1993). In this area the dune ecosystems have been more affected compared to rock or cliff ecosystems. The main forces are agriculture (sugarcane plantations, overgrazing, forest clearing, veld burning), mining of heavy metals,

tourism, and industrialisation. The developments of cities and coastal resorts have, together with modern agriculture, left their mark on the coastal area by destroying the original vegetation (Weisser & Cooper 1993). Besides direct human impact through development, many coastal areas suffer from heavy infestation by alien plants—species of *Acacia* along the South/Southeast coasts, and *Chromolaena odorata, Lantana camara* and species of *Pereskia* along the East Coast.

Some of these threats to the sandy beaches and dunes were already recognised decades ago and stated as a potential problem (i.e. Avis 1986, 1992). As is obvious from the above-mentioned threats, they remain a problem. Fortunately some action has been taken. For instance, the aliens are currently being removed by the local Working for Water (DWAF 2005) campaign (Figure 14.19), and many of the coastal areas are protected and preserved in conservation areas and this should be an ongoing process!

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Figure 14.19 Alien Australian shrubby *Acacia cyclops* (rooikrans) is a prime target of the Working for Water alien plant eradication programme. Freshly cut rooikrans is left on the steep dune slopes to curb erosion and facilitate the establishment of native dune shrubs (Diaz Cross site near Boknes, Eastern Cape coast).

Priorities to any further development should be in terms of requirements of conservation and responsible tourism, rather than in terms of industrial endeavours that could equally well be situated inland, as stated by Heydorn & Tinley (1980). A more effective system of land use management and planning is required, one that would more effectively discourage coastal sprawl and encourage more compact, nodal developments.

The current state of biodiversity protection of South African sandy coast is reasonable. Not all vegetation units have the status of 'vulnerable'. Most are considered to be 'least threatened', even though the sandy beaches and dunes of the South African coast are known as sensitive systems that can easily be damaged or disrupted (Tinley 1985, Lubke et al. 1997, Turpie 2004b; see also Conservation sections in the descriptions of the vegetation units below).

7. Future Research

The coast is a place subject to direct and indirect influences—especially the human impact on the coastal system is enormous (i.e. building of roads, houses and resorts, mining of dunes, building of harbours and breakwaters, pollution). Therefore this distinctive and complex system requires a dedicated management effort.

The *ad hoc*, sectoral management approach that was common along the coast the last years ignored the wider consequences of local activities, and failed to realise the full spectrum of benefits provided by the coastal system. Management should focus on the coastal system as a whole and force decision-makers and developers to recognise that individual actions might have system-wide consequences.

However, before a proper management plan can be set in motion, it is of great importance to understand the interrelationships between the natural and human components of the coastal system, to improve sustainable development and to resolve conflicting coastal issues, to name a few. Knowledge and understanding of the (local) coastal ecosystem is thus significant. This information is needed, for instance, to restore or rehabilitate damaged or destructed coastal areas, or to predict what (long-term) effects certain activities will have on the coastal system. To be able to make these predictions, long-term monitoring programmes will be needed to follow the changes in the dune ecosystem (i.e. removal of alien plants, any coastal development), but also to alert (local) management authorities of potential problems so that appropriate actions might be taken before irreversible damage is done.

Besides the need for monitoring, there is unfortunately still a lack of knowledge on the (local) ecological processes that are a fundamental part of the sandy shore. This type of research will be needed to be able to answer questions such as:

- Which indigenous species are suitable for rehabilitation/restoration projects? What are their growth/reproductive requirements (water, light, temperature)?
- What is the current status of endangered and alien species? Which species might be endangered in the future?
- What will happen when the climate changes? Will alien noninvading species become invasive?
- What is the status of protected areas? Which coastal environments/areas/features need protection?
- What is the impact of current and future recreational activities and developments?

Answers to these questions are needed to be able to consider the long-term and cumulative impacts on the coastal area and its reaction to these impacts.

Past coastal management approaches have been fragmented and poorly co-ordinated between the different spheres of government, largely due to a lack of capacity to perform coastal management functions. Due to a lack of clarity on the roles and responsibilities between various departments, certain areas of the coastal zone have been poorly managed. As a result, a people-centred approach to coastal management was adopted in the recent Policy Document: The White Paper for Sustainable Coastal Development (DEAT 2000). This national policy provides the guiding principles for coastal management in South Africa and led to the development of Provincial Coastal Management Programmes (DEAT 2000).

Besides the obvious enormous importance for the South African economy (especially tourism and fisheries) and associated applied research, the needs for fundamental research into origins of the coastal habitats, evolution of its biota, biodiversity patterns, and processes generating those patterns, are far from being met. Although South African coasts rank undoubtedly among the best researched ecosystems in the region (Lubke et al. 1997, Whitfield 2000, and this chapter), it would be wrong to assume we know enough to conserve and exploit these fragile systems wisely. Turpie (2004b) named a few gaps that estuarine research should address, namely a review of the estuary classification system to (1) devise a more robust system useful in applied conservation research, (2) develop methods for quantitative assessment of estuary health, and (3) quantify interactions between estuarine and marine systems. We believe that at least with regard to point (1), our Map and this chapter with a new classification of coastal vegetation units is a step in the right direction. We wish to add that some aspects of biodiversity research are still needed. More vegetation-oriented research looking into local variability of habitat-level community types is needed. New species of plants are awaiting formal description. Coasts are a fascinating biogeographical subject, offering excellent models for study of evolutionary processes shaping biodiversity on many levels of complexity (from local populations to large-scale vegetation complexes).

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Figure 14.20 AZm 1 Cape Kelp Beds: *Ecklonia maxima* kelp bed near Betty's Bay (Western Cape).

8. Descriptions of Vegetation Units

Algal Beds

AZm 1 Cape Kelp Beds

Distribution Western and Northern Cape Provinces: Along the West Coast of South Africa, from a few km west of Cape Agulhas as far north as Rocky Point in northern Namibia. Smaller kelps (*Ecklonia radiata*) occur eastwards as far as KwaZulu-Natal, but do not form kelp beds.

Vegetation & Seascape Features In the south (coastline of the Western Cape Province), inshore beds are dominated by the sea bamboo *Ecklonia maxima*, with plants up to 15 m long. In this region, *Ecklonia* forms a dense canopy from the subtidal fringe to ca. 10 m deep. In sheltered coves and in deeper water (down to ca. 14 m) solid-stiped plants of *Laminaria pallida* are dominant (Bolton & Anderson 1994, 1997, Stegenga et al. 1997). *Laminaria* is rare east of Cape Point, but further north (coastline of the Northern Cape Province) plants have a hollow stipe and tend to be dominant inshore, with *Ecklonia maxima* being rarer. These hollow-stiped *Laminaria* plants formerly known as *Laminaria schinzii*, were considered a variety of *L. pallida* by Stegenga et al. (1997). West of Cape Point, there is a dense understorey of foliose seaweeds, dominated by red algae such as *Botryocarpa prolifera*, *Hymenena venosa*, *Neuroglossum binderianum* and *Epymenia obtusa*. Between Cape Point and Cape Agulhas, there are large numbers of grazers present (sea urchins, abalone etc.), and much of the bottom is covered with grazer-resistant crustose coralline red algae (Anderson et al. 1997, Leliaert et al. 2000). The only other kelp present (*Macrocystis angustifolia*) is rare, occurring only in relatively small populations inshore of *Ecklonia maxima* beds, at a few sites from the Cape Peninsula to Paternoster.

Hydrology & Substrate Kelp beds occur on the West Coast wherever there is rocky substrate in shallow water. The marine environment is dominated by the Benguela Upwelling System, which is driven by the longshore Southeaster (wind), mainly occurring in summer. The West Coast marine flora is generally considered cool-temperate (Bolton & Anderson 1997), with absolute minimum temperatures around 8ºC, but monthly means not dropping below 11ºC or rising above 15ºC (Bolton 1986) on most of the west coast. In False Bay, *Ecklonia* beds thrive in warmer temperatures (monthly mean of almost 20ºC in summer), whereas *Laminaria* is uncommon east of the Cape Peninsula.

Important Taxa Kelp: *Ecklonia maxima* (d), *Laminaria pallida* (d), *Macrocystis angustifolia* (d). Foliose Algae: *Botryocarpa prolifera* (d), *Hymenena venosa* (d), *Neuroglossum binderianum* (d), *Epymenia obtusa* (d). Epiphytic Algae (both on *Ecklonia maxima*): *Suhria vittata, Carradoria virgata.* Parasitic Algae: *Carpoblepharis flaccida* (on *Ecklonia maxima*), *C. minima* (on *Laminaria pallida*).

Conservation West Coast kelps have been utilised commercially for many decades, dried and shipped overseas for alginate production (Anderson et al. 2003). In addition, for many years small amounts (ca. 50 tons fresh weight per year) have been cut near Kommetjie for the production of the fertiliser supplement Kelpak®. In the last few years, kelp has been harvested in ever-increasing amounts (reaching 6 000 tons wet weight per year currently) for use as feedstock in the rapidly growing onshore abalone aquaculture industry. The available kelp in some areas is reaching sustainable limits. The kelp beds are protected, for example around the Cape Peninsula in the Marine Protected Areas within the Restricted Zones of Karbonkelberg, Kalk Bay, Boulders, Castle Rock, Paulsberg and Cape of Good Hope (coastal waters of the Table Mountain National Park).

Remark 1 The West Coast *Ecklonia* beds have been calculated to produce between 4.1 and 7.8 kg dry mass m^{-2} y^{-1} (Newell et al. 1980), and *Laminaria* stands have been shown to turn over

twice per year, with a production of 27.9 kg wet mass m^{-2} y^{-1} (Dieckmann 1980).

Remark 2 Annual production of *Ecklonia maxima* has been calculated to lose 10% as a result of storms (Simons & Jarman 1981). The large quantities of drift kelp which consequently wash up on West Coast beaches support a characteristic fauna of small crustaceans, which in turn provide food for birds and larger crustaceans (Griffiths et al. 1983).

Remark 3 The extent of the Cape Kelp Beds has not been captured in the current version of the Map.

References Dieckmann (1980), Newell et al. (1980), Simons & Jarman (1981), Griffiths et al. (1983), Bolton (1986), Bolton & Anderson (1994, 1997), Stegenga et al. (1997), Leliaert et al. (2000), Anderson et al. (2003).

Estuarine Vegetation

AZe 1 Arid Estuarine Salt Marshes

Distribution Northern Cape and Western Cape Provinces: At mouths of the Namaqualand rivers such as the Orange (Gariep), Buffels, Swartlintjies, Spoeg, Bitter, Groen, Sout and Olifants Rivers. Further north this salt-marsh unit is found at river mouths along the Namib Desert coast of Namibia as far as southern Angola.

Vegetation & Landscape Features Estuarine salt marshes in the river mouths with patches of supratidal salt marshes on elevated terraces. Vegetation is formed mainly of low succulent dwarf shrubland patches, forming a mosaic with creeping grassy mats and patches of reed beds.

Geology, Soils & Hydrology Recent riverine (and partly also marine) sediments, with Table Mountain Group quartzitic sandstones and Gariep Supergroup metasediments (underlying the estuaries) are exposed in places (i.e. Olifants and Orange Rivers). The intertidal and supratidal salt marshes experience regular tidal action (diurnal and spring tidal, respectively) that is responsible for sediment deposition and erosion. The floodplains were formed through ancient alluvial sedimentary processes (palaeo-floodplains) and do not experience flooding under present river flows. The floodplain salt marsh uses the groundwater where the groundwater depth is less than 1.5 m and the salinity is less than 70 ppm.

Climate Arid, characterised by cool-temperate regime (MAT close to 18°C) with a very low, erratic MAP, ranging from less than 150 mm at Lutzville (Olifants estuary) to 45 mm at Alexander Bay (Orange estuary). Rain generally falls in wind-driven showers spread over the season from May to August, but it can (in some years) fall with a single heavy shower. The air passing from the cold Benguela Upwelling System onto the land surface gives rise to the frequent occurrence of fog. On average fog occurs for 89 and 48 days at the Orange and Olifants estuaries, respectively. The greatest occurrence of fog is from March to September. The importance of fog for the salt-marsh plants in semi-arid environments has not yet been quantified, but it is expected to be significant. The region is generally frost-free. See also climate diagram for AZe 1 Arid Estuarine Salt Marshes (Figure 14.3).

Important Taxa Estuarine water bodies: Aquatic Herb: *Potamogeton pectinatus*. **Tidal salt marshes**: Succulent Shrub: *Chenolea diffusa*. Herb: *Cotula coronopifolia*. Geophytic Herb: *Triglochin striata*. Succulent Herb: *Salicornia meyeriana* (d). Graminoids: *Juncus kraussii* subsp. *kraussii* (d), *Sporobolus virginicus* (d), *Ficinia nodosa, Juncus acutus* subsp. *leipoldtii, J. rigidus*. **Supratidal terraces**: Succulent Shrubs: *Salsola zeyheri*, *Suaeda fruticosa*. Succulent Herb: *Psilocaulon dinteri*. Graminoids: *Odyssea paucinervis* (d), *Phragmites australis* (d).

Biogeographically Important Taxa Supratidal terraces: Succulent Shrubs: *Lycium decumbens* (Gariep endemic), *Sarcocornia natalensis* var. *affinis* (West Coast endemic).

Conservation Least threatened. Target 24%. None conserved in statutory conservation areas. Some 15% transformed for cultivation or by mining (diamond prospecting) activities.

L. Mucina

Figure 14.21 AZe 1 Arid Estuarine Salt Marshes: Decaying lagoon of the Jakkals River at Lambert's Bay (Western Cape) after being artificially cut off from the tidal influence of the sea. The centre of the lagoon is dry at present and covered with a papery layer of dead algal bloom and a species of *Ruppia*, while the banks support typical supratidal halophilous vegetation with chenopods *Sarcocornia natalensis* var. *affinis* (pink patches), *Salicornia meyeriana* (deep red patches) and *Atriplex prostrata* subsp. *austroafricana* (in the foreground).

Remarks Estuaries in Namaqualand (south of Kleinzee) are relatively undisturbed, except for salt works in the Olifants and Sout Rivers. Increased freshwater abstraction in the Olifants estuary is a major threat, which would cause salinity intrusion into the middle reaches of the estuary in summer and loss of brackish habitats (*Cotula coronopifolia*, *Juncus kraussii*). An increase in groundwater salinity would result in die-back of the large supratidal and floodplain areas. The Orange estuary has also been impacted by freshwater alteration and die-back of a large floodplain salt-marsh area. Although barren areas are a natural feature of salt marshes on the West Coast of southern Africa, more than 70 ha have been lost at the mouth of the Orange River through bad management practices. Large-scale die-back of reed beds (mostly *Schoenoplectus scirpoideus* and *Phragmites australis*) occurs in the lower reaches of the Orange estuary as, in response to the low flows, saline water is pushed higher up the river.

References Day (1981b), Parsons & Le Roux

(1981a–f), Morant & O'Callaghan (1990), Boucher & Le Roux (1993, 1994), Lubke et al. (1997), Bornman (2002), Boucher (2003), Bornman et al. (2004a, b).

AZe 2 Cape Estuarine Salt Marshes

Distribution Western Cape and Eastern Cape Provinces: Estuaries and coastal salt-marsh plains of temperate coasts of the Atlantic Ocean from Lambert's Bay on the West Coast as far as the mouth of the Great Kei River (Eastern Cape) on the Indian Ocean coast. The most important estuarine systems of this type include salt marshes located at the Berg, Uilkraalsmond, Breede, Goukou, Groot and Klein Brak, Keurbooms/Bitou, Kromme, Seekoei, Kabeljous, Gamtoos, Swartkops, Kowie, Bushmans (penetrating inland as deep as Ghio Marsh), Kariega, Great Fish, Buffels, Keiskamma and Great Kei Rivers as well as estuarine lakes such as Kleinmond, De Mond (near Struisbaai), Swartvlei and estuarine bays such as Knysna Lagoon.

Vegetation & Landscape Features Estuarine flats and systems of low riverine terraces supporting complexes of low herblands and shrublands dominated by succulent chenopods and other flood-tolerant halophytes (especially on supratidal terraces and in middle and lower tidal zones), salt-marsh meadows dominated by rushes and sedges (often indicating freshwater seeps), *Spartina* swards and (temporary) submerged *Zostera* sea meadows at the lower boundary of the tidal zone.

Geology, Soils & Hydrology Most Cape estuaries drain Table Mountain Sandstone vegetated with Fynbos that gives the riverine water a characteristic black colour (high tannin load and low pH), with low amounts of sediment (medium-grained sand). The estuarine sediment has an increasingly higher clay fraction as one moves east due to the Karoo sediments through which these rivers drain, e.g. the Kromme, Gamtoos, Sundays Rivers, etc. Recent sandy sediments of layered mixed riverine and marine origin are submitted to a diurnal tidal flooding regime. The highest terraces are flooded only at the highest tides. Floodplains are flooded only during river floods. Floodplain salt marshes in estuaries with floodplains, e.g. the Berg, Breede, Gourits, Kromme and Gamtoos Rivers, are still dependent on groundwater as their major source of water, but the higher rainfall creates a higher cover of *Sarcocornia pillansii* and an increase in brackish species. The tidal range varies greatly; for instance in False Bay it is 0.5–2 m.

Climate Warm-temperate winter-rainfall (Atlantic coast and False Bay) and transitional winter-summer-rainfall (eastwards of the Cape Hangklip) regions. MAP between 175 mm (Lambert's Bay) and 850 mm (Garden Route). MAT from 16.0°C (Overberg) to 17.8°C (Albany region). The coastal waters and coastal climate of the region is under the decisive influence of the coastal cold-water upwellings of the Benguela Current (along the west coast) and of the cold Agulhas Counter-Current. Easterly winds in summer create localised coastal upwelling events along the South Coast that may decrease the estuarine water temperature by as much as 10°C (Schumann 2000). See also climate diagram for AZe 2 Cape Estuarine Salt Marshes (Figure 14.3).

Important Taxa **Estuarine water bodies**: Graminoids: *Ruppia cirrhosa* (d), *R. maritima* (d), *Zostera capensis* (d). **Tidal salt marshes**: Succulent Shrubs: *Chenolea diffusa* (d), *Sarcocornia perennis* complex (d). Low Shrubs: *Samolus porosus* (d). Herbs: *Cotula filifolia*, *Seidelia pumila*. Geophytic Herbs: *Triglochin bulbosa* complex (d), *Romulea tabularis, Triglochin striata*. Succulent Herbs: *Spergularia media* complex (d), *Plantago crassifolia* complex (d), *Salicornia meyeriana* (d), *Cotula coronopifolia*, *Suaeda inflata*. Graminoids: *Juncus kraussii* subsp. *kraussii* (d), *Spartina maritima* (d), *Sporobolus virginicus* (d), *Puccinellia angusta*, *Schoenoplectus triqueter*, *Stenotaphrum secundatum*. **Supratidal terraces**: Succulent Shrubs: *Disphyma crassifolium* (d), *Sarcocornia capensis* (d), *S. pillansii* (d). Graminoid: *Stenotaphrum secundatum* (d).

Biogeographically Important Taxa (both West Coast endemics) **Supratidal terraces**: Succulent Shrub: *Sarcocornia natalensis* var. *affinis* (d). Herb: *Limonium decumbens* (d).

Endemic Taxa **Tidal salt marshes**: Succulent Herbs: *Poecilolepis ficoidea*, *P. maritima*.

Conservation Least threatened. Target 24%. Already 21% statutorily conserved in the West Coast (including much of the Langebaan Lagoon) and Garden Route National Parks (including Knysna Lagoon), Rietvlei, Kleinmond, Walker Bay, De Mond, Swartkops Valley, Seekoei, Kabeljous River, Kap River, Great Fish River Wetland as well as in the private Emlanjeni Game Reserve (near Kenton-on-Sea). Langebaan Lagoon and the De Mond estuary are Ramsar sites. Some 14% transformed for cultivation, by urban sprawl, mining or road building.

L. Mucina

Figure 14.22 AZe 2 Cape Estuarine Salt Marshes: Tidal salt marsh in the head of the Langebaan Lagoon (West Coast National Park), with clones of *Sarcocornia perennis* complex (Chenopodiaceae), *Sporobolus virginicus* (Poaceae) and *Limonium decumbens* (Plumbaginaceae) forming a mosaic with algal slick patches.

References Dyer (1937), Boucher & Jarman (1977), Howard-Williams & Liptrot (1980), Day (1981b), Heinecken (1981, 1982a, b, 1985), Bickerton (1982, 1984), Cliff & Grindley (1982), Grindley (1982, 1985), Heinecken & Grindley (1982), Heinecken et al. (1982), Heydorn & Bickerton (1982), Koop (1982), Morant & Grindley (1982), Boucher (1983, 1987, 1998c–e), Carter (1983), Heinecken & Damstra (1983), Lubke (1983), Morant (1983, 1984), Morant & Bickerton (1983), Whitfield et al. (1983), Wiseman et al. (1983), Duvenhage & Morant (1984), Baird et al. (1986), Sinclair et al. (1986), Bickerton & Pierce (1988), Burns et al. (1988), Grindley (1988), Grindley & Dudley (1988), Boucher & Le Roux (1989), Clarke (1989), De Decker (1989), Heydorn (1989b), Bloemhoff & Craven (1990), Carter & Brownlie (1990), O'Callaghan (1990a, b, 1994a–e), Adams (1991), Morant (1991), Lubke et al. (1997), Adams et al. (1999), Allanson & Baird (1999), Boucher & Rode (1999), Colloty et al. (2000, 2001, 2002), Schumann (2000), Withers et al. (2002), Mucina et al. (2003).

AZe 3 Subtropical Estuarine Salt Marshes

L. Mucina

Figure 14.23 AZe 3 Subtropical Estuarine Salt Marshes: Grasses *Sporobolus virginicus* and *Paspalum distichum* are dominant in salt marsh grassland on the edge of a brackish coastal lagoon isolated from the sea by a sand bar (in the background)—Thompson's Lagoon at the Wild Coast Sun complex on the Eastern Cape/KwaZulu-Natal border.

Distribution Eastern Cape and KwaZulu-Natal Provinces: The subtropical coasts of Indian Ocean from north of Kei Mouth eastwards as far as the border between KwaZulu-Natal and Mozambique. The occurrence of the Subtropical Estuarine Salt Marshes roughly parallels the extent of the Mangrove Forest in South Africa.

Vegetation & Landscape Features Estuaries and coastal salt-marsh plains supporting complexes of low herblands dominated by succulent chenopods and other flood-tolerant halophytes. Also containing salt-marsh meadows dominated by rushes and sedges, *Spartina*-flooded swards and submerged *Zostera* sea meadows.

Geology, Soils & Hydrology Recent sandy sediments of mixed marine and riverine origin submitted to a diurnal tidal flooding regime. A high average salinity of water (18–23 g of soluble salt per litre) was recorded in the southernmost permanently open estuaries of this unit (Group B in Colloty et al. 2002). The estuaries on the KwaZulu-Natal coast usually have a lower salinity, often containing brackish mud flats fringing mangroves.

Climate Subtropical, year-round precipitation patterns with higher precipitation in summer (especially along the KwaZulu-Natal coast). MAP 932 mm (Maputaland) to 1 014 mm (Transkei). MAT 18.4°C (Transkei) to 21.1°C (Maputaland). The coastal waters as well as the climate of the coasts hosting this type of estuarine vegetation are under the influence of the warm Agulhas Current. No frost has been recorded. See also climate diagram for AZe 3 Subtropical Estuarine Salt Marshes (Figure 14.3).

Important Taxa **Estuarine water bodies**: Graminoids: *Spartina maritima* (d), *Zostera capensis* (d), *Halodule uninervis*, *Halophila ovalis*, *Thalassodendron ciliatum*. **Tidal salt marshes**: Succulent Shrub: *Chenolea diffusa* (d). Low Shrub: *Samolus porosus*. Geophytic Herbs: *Triglochin striata* (d), *T. bulbosa* complex. Succulent Herbs: *Sarcocornia natalensis* complex (d), *Salicornia pachystachya*. Graminoids: *Cyperus laevigatus* (d), *Juncus kraussii* subsp. *kraussii* (d), *Schoenoplectus litoralis* (d), *Sporobolus virginicus* (d). **Supratidal terraces**: Succulent Shrubs: *Disphyma crassifolium* (d), *Sarcocornia pillansii* (d). Herbs: *Atriplex patula* subsp. *verreauxii*, *Ethulia conyzoides* subsp. *kraussii*, *Nidorella linifolia*. Graminoids: *Paspalum vaginatum* (d), *Pycreus polystachyos*, *Stenotaphrum secundatum*.

Conservation Least threatened. Target 24%. Unknown percentage statutorily conserved in the Dwesa-Cwebe Wildlife Reserve & Marine Sanctuary, Mpenjati, Beechwood, Umgeni Lagoon, Amathikulu, Umlalazi and Richards Bay Nature Reserves as well as in the Greater St Lucia Wetland Park. Threats: dune mining, development (especially in KwaZulu-Natal), increased freshwater runoff and nutrient input from sugar cane fields (agriculture) and increased sedimentation and turbidity from soil erosion in catchment exacerbated by poor agricultural practices.

Remark 1 Low species diversity and limited extent of the Subtropical Estuarine Salt Marshes as compared to the AZe 2 Cape Estuarine Salt Marshes in South Africa support the general notion of the estuarine salt marshes being a temperate vegetation system.

Remark 2 A further four species (*Halodule wrightii, Cymodocea rotundata, C. serrulata* and *Syringodium isoetifolium*) of rhizomatous dioecious seagrasses of the family Cymodoceaceae found in sublittoral (and partly intertidal) 'sea meadows' have been reported form Maputo (Delagoa) Bay in Mozambique (Cook 2004).

References Day et al. (1953), Broekhuysen & Taylor (1959), Edwards (1967), Venter (1972), Campbell (1976), Begg (1978), Ward (1980), Day (1981b), Lubke et al. (1997), Adams et al. (1999), Allanson & Baird (1999), Colloty et al. (2000, 2001, 2002), Taylor et al. (2006).

Seashore Vegetation

AZd 1 Namib Seashore Vegetation

Distribution Northern Cape Province: Richtersveld coast, between the Holgat River and Orange River mouth. Larger portion of this unit extends further north along the Sperrgebiet coast into Namibia.

Vegetation & Landscape Features Slightly sloping beach and adjacent moving and fixed sand dunes with vegetation dominated by dwarf shrubs up to 1 m tall and spiny grasses on the windblown dunes. Small succulent dwarf shrubs are dominant on exposed rocky cliffs on the seafront.

Geology, Soils & Hydrology Recent marine sandy sediments forming beaches and coastal dunes (Strandveld Formation) and overlying Gariep Supergroup metasediments and metavolcanics. Not subjected to submersion, but under constant maritime influence (sea spray).

Climate Hostile, arid coast with the lowest precipitation in South Africa (45 mm at Alexander Bay). Fog is almost always present in winter at night and in the early morning. Because of the exceptionally low rainfall, the vegetation depends largely on sea fog as a source of moisture. MAT 17.2°C at Alexander Bay (see also climate diagram in Figure 6.2). Temperature does not vary greatly between winter and summer.

L. Mucina

Figure 14.24 AZd 1 Namib Seashore Vegetation: Coastal dunes of blown sand and shell debris at Diaz Point near Lüderitz (Namibia). The tall whitish shrub on the dune is *Salsola* cf. *nollothensis* (Chenopodiaceae), with the low cushion-forming *Zygophyllum clavatum* (Zygophyllaceae).

Important Taxa Succulent Shrubs: *Lycium tetrandrum* (d), *Tetragonia fruticosa* (d), *Didelta carnosa* var. *tomentosa*, *Zygophyllum clavatum*. Succulent Herb: *Psilocaulon dinteri*. Low Shrubs: *Atriplex vestita* (d), *Asparagus capensis* var. *littoralis*, *Hebenstretia cordata*. Herb: *Polygonum maritimum*. Graminoid: *Cladoraphis cyperoides* (d).

Biogeographically Important Taxa ([W]West Coast endemic, [G]Gariep endemic) Succulent Shrubs: *Salsola nollothensis*[W] (d), *Amphibolia rupis-arcuatae*[W], *Arctotis scullyi*[W], *Brownanthus marlothii*[G], *Drosanthemum luederitzii*[W], *Hypertelis angraepequenae*[W], *Lycium decumbens*[G]. Succulent Herb: *Fenestraria rhopalophylla* subsp. *aurantiaca*[W]. Herb: *Limonium* sp. nov.[W] (*Mucina 7238/8* STEU).

Conservation Vulnerable. Target 26%. None conserved in statutory conservation areas, but some off limits to the public due to coastal diamond mining, which is responsible for transformation of 14% of the area of the unit. Heavy minerals are also found here, but they have not yet been subject to exploitation.

References Boucher & Le Roux (1981, 1993), Williamson (1997).

AZd 2 Namaqualand Seashore Vegetation

Distribution Northern Cape Province: Namaqualand, very narrow strip above the high tide zone along the sea from the Holgat River to just south of the Olifants River.

Vegetation & Landscape Features Slightly sloping beach, coastal rocky formations supporting sparse vegetation composed of (partly) succulent hummock-forming and spreading dwarf shrubs and herbs on the beach, in shell beds and on low dunes. Leaf succulent chenopod shrubs are dominant on coastal cliffs and shell beds.

Geology, Soils & Hydrology Recent sandy marine sediments forming beaches and coastal dunes and extensive deep shell beds. The coastal cliffs consist of either Gariep Supergroup quartzitic sandstones or Mokolian granites and gneisses. Outside the direct influence of the sea (submersion), but under constant maritime influence (salt spray).

Climate Hostile, arid coast characterised by erratic rainfall, high solar irradiation and frequent desiccating winds. MAP 105 mm, increasing from around 60 mm (Port Nolloth) in the north to 150 mm (Strandfontein) in the south. Fog present in winter at night and in the early morning. MAT 17.6°C and seasonal temperature has a slightly higher variation than that of AZd 1 Namib Seashore Vegetation. Incidence of frost negligible. See also climate diagram for AZd 2 Namaqualand Seashore Vegetation (Figure 14.3).

Important Taxa **Shell beds**: Succulent Shrub: *Zygophyllum cordifolium* (d). Succulent Herbs: *Psilocaulon dinteri* (d), *Arctotheca populifolia*, *Mesembryanthemum guerichianum*. Low Shrub: *Frankenia repens*. **Dunes & beaches**: Succulent Shrubs: *Sarcocornia littorea* (d), *Crassula plegmatoides*, *C. tomentosa*, *Didelta carnosa* var. *tomentosa*, *Lycium tetrandrum*, *Othonna floribunda*, *Stoeberia utilis*, *Tetragonia decumbens*, *T. fruticosa*, *Zygophyllum morgsana*. Low Shrubs: *Atriplex vestita* (d), *Lebeckia cinerea* (d), *Asparagus capensis* var. *litoralis*, *Hebenstretia cordata*. Herbs: *Dasispermum suffruticosum*, *Polygonum maritimum*. Geophytic Herb: *Trachyandra divaricata*. Graminoids: *Cladoraphis cyperoides* (d), *Sporobolus virginicus*.

Biogeographically Important Taxa (all West Coast endemics) **Shell beds**: Succulent Shrubs: *Drosanthemum luederitzii*

L. Mucina

Figure 14.25 AZd 2 Namaqualand Seashore Vegetation: Upper-beach habitat with *Sarcocornia terminalis* (Chenopodiaceae), *Psilocaulon dinteri* and the alien *Salsola kali* north of Strandfontein near the mouth of the Olifants River (Western Cape).

L. Mucina

Figure 14.26 AZd 2 Namaqualand Seashore Vegetation: Shell beds on the beach at Mc Dougall's Bay (Port Nolloth, Northern Cape), with shrubby chenopods *Salsola nollothensis* and the leaf-succulent *Zygophyllum rotundifolium* (Zygophyllaceae).

(d), *Hypertelis angrae-pequenae*. Herb: *Limonium* sp. nov. (*Mucina 7238/8* STEU). **Dunes & beaches**: Succulent Shrubs: *Amphibolia rupis-arcuatae* (d), *Salsola nollothensis* (d), *Arctotis scullyi*, *Vanzijlia annulata*. Succulent Herb: *Fenestraria rhopalophylla* subsp. *aurantiaca*. **Cliffs**: Herb: *Limonium decumbens*.

Endemic Taxa Dunes & beaches: Herbs: *Gazania* sp. nov. (*Mucina 050905/02* STEU), *Limonium* sp. nov. ('*diamanticolum*') (*Mucina 050905/13* STEU).

Conservation Target 26%. None conserved in statutory conservation areas. Diamond mining in this area is a great threat to the strand vegetation whether it is land surface or marine mining (about 5% of the area of this unit has already been transformed). Heavy minerals are intensively mined near Brand-se-Baai and although the present mining is not yet on the strand, it will extend to the beaches. The guided Diamond Coast 4x4 trail runs through a restricted-access part of this unit between Noup and Kleinzee, providing some measure of protection. Establishment of a national park (including the coast between the Spoeg and Groen River mouth) is currently being negotiated.

Remark *Amphibolia rupis-arcuatae* and *Fenestraria rhopalophylla* subsp. *aurantiaca* are found only from the vicinity of Kleinzee northwards to the Orange River mouth, indicating a floristic relationship between the Namib and Namaqualand Seashore units.

References Boucher & Le Roux (1981, 1989, 1993), L. Mucina (unpublished data).

AZd 3 Cape Seashore Vegetation

Including *Didelta–Psoralea* Littoral-dune Open Grassland (Boucher & Jarman 1977). *Ehrharta–Ficinia* Strand Pioneers (Boucher 1978). *Tetragonia decumbens–Agropyron distichum* Fore-dune Community (O'Callaghan 1990a).

Distribution Western Cape and Eastern Cape Provinces: Temperate coasts of the Atlantic Ocean (Olifants River mouth to Cape Agulhas) and Indian Ocean (Cape Agulhas to East London). According to Tinley (1985; see also Lubke et al. 1997), this stretch of coast comprises the South West and South Coasts.

Vegetation & Landscape Features Beaches, coastal dunes, dune slacks and coastal cliffs of open grassy, herbaceous and to some extent also dwarf-shrubby (sometimes succulent) vegetation, often dominated by a single pioneer species. Various plant communities reflect the age of the substrate and natural disturbance regime (moving dunes), distance from the upper tidal mark and the exposure of dune slopes (leeward versus seaward).

Geology, Soils & Hydrology Young coastal sandy sediments forming beaches and dunes (Strandveld Formation), exposed to reworking by relentless winds and frequent sea storms. Some stretches of the West Coast are covered by extensive shell beds.

Climate The climate diagram for this unit (Figure 14.3) shows a largely uniform, all-year precipitation pattern, but this pattern must be interpreted with care since the unit encompasses regions of very diverse precipitation regimes. The West Coast (under influence of the Benguela Current) and the portion of the South Coast bordering on the Atlantic Ocean are characterised by cold seawater and frequent upwelling events. The local precipitation is low (as low as 100 mm in places) and typically seasonal (winter-rainfall peak). From Cape Agulhas westwards the coast is influenced by occasional eddies of the Agulhas Current, but the water stays generally cold. The precipitation becomes transitional, with a considerable increase of summer rainfall eastwards. MAP in Lambert's Bay, Cape Town, Plettenberg Bay and Port Elizabeth is 128 mm, 517 mm, 661 mm and 604 mm, respectively. The temperature varies less than precipitation (17–18°C for both Lambert's Bay and Port Elizabeth). See also climate diagram for this unit (Figure 14.3).

Important Taxa Dunes & beaches: Succulent Shrubs: *Drosanthemum candens* (d), *Pelargonium capitatum* (d), *Tetragonia decumbens* (d), *Didelta carnosa* var. *tomentosa*, *Exomis microphylla* var. *axyrioides*, *Lycium tetrandrum*, *Scaevola plumieri*. Low Shrubs: *Hebenstretia cordata* (d), *Frankenia repens*, *Oncosiphon sabulosum*. Semiparasitic Shrub: *Thesidium fragile*. Herbaceous Climbers: *Cynanchum ellipticum*, *C. obtusifolium*. Herbs: *Gazania rigens* (d), *Senecio littoreus* (d), *Amellus asteroides*, *Dasispermum suffruticosum*, *Manulea tomentosa*, *Polygonum maritimum*, *Senecio elegans*. Geophytic Herb: *Trachyandra divaricata*. Succulent Herbs: *Arctotheca populifolia* (d), *Carpobrotus acinaciformis*, *C. edulis*. Graminoids: *Cladoraphis cyperoides* (d), *Ehrharta villosa* var. *maxima* (d), *Sporobolus virginicus* (d), *Stipagrostis zeyheri* subsp. *barbata*. **Cliffs**: Succulent Shrubs: *Disphyma crassifolium* (d), *Sarcocornia littorea* (d). Herb: *Gazania rigens* (d).

Endemic Taxa Dunes & beaches: Low Shrub: *Psoralea repens* (d). Succulent Shrub: *Amphibolia laevis* (d). Herbs: *Amellus capensis*, *Gazania maritima*, *G. rigens* var. *leucolaena*, *Silene crassifolia*. Succulent Herbs: *Senecio litorosus*, *S. maritimus*. Graminoids: *Thinopyrum distichum* (d), *Eragrostis sabulosa*. **Dune slacks**: Herb: *Vellereophyton vellereum*. **Cliffs**: Succulent Shrubs: *Drosanthemum marinum* (d), *D. stokoei*, *Erepsia steytlerae*, *Prenia vanrensburgii*. Low Shrub: *Syncarpha sordescens*. Herbs: *Limonium* sp. nov. (*Mucina 6942/1* STEU), *Lobelia boivinii*.

Conservation Least threatened. Target 20%. Almost half of the area statutorily conserved in the West Coast, Cape Peninsula,

L. Mucina

Figure 14.27 AZd 3 Cape Seashore Vegetation: Dune cordons in De Mond Nature Reserve near Arniston (Western Cape), close to Cape Agulhas (the southernmost point of the African continent). The dominant grasses are *Thinopyrum distichum* and *Ehrharta villosa* var. *maxima* and the yellow-flowered daisy is *Didelta carnosa* var. *tomentosa*.

Agulhas, proposed Garden Route and Greater Addo Elephant National Parks as well as the Rocher Pan, Cape Columbine, Dassen Island, Wolvengat, Kleinmond, Walker Bay, De Mond (Ramsar site), De Hoop, Kleinjongensfontein, Geelkrans, Robberg, (all Western Cape), and Cape St Francis, Cape Recife, Joan Muir, Gxulu, Cape Henderson, Kwelera and Bosbokstrand Nature Reserves (all Eastern Cape). A number of private conservation areas such as Donkin Bay, Robben Island, Rein's Coastal Reserve and Tharfield Nature Reserve protect other considerable portions of the Cape Seashore Vegetation. Only about 1.7% has been transformed, mainly by urban development.

Remark Extensive dunefields are found at De Hoop, Cape St Francis, Gamtoos, Alexandria and Boknes along this coastal stretch (Tinley 1985, Young 1987, Talbot & Bate 1991).

References Muir (1929), Dyer (1937), Martin & Noel (1960), Comins (1962), Boucher (1972, 1977, 1978, 1986, 1987, 1989, 1992, 1993, 1994, 1995, 1997, 1998a, b, c, e, 1999a–e), Heydorn (1975), Boucher & Jarman (1977), Boucher & Le Roux (1981), Taylor & Morris (1981), Van Rooyen (1981), Lubke & Avis (1982a, b, 1988, 2000), Lubke (1983), Boucher et al. (1986), La Cock (1986), McLachlan et al. (1987), Young (1987), Avis (1989, 1992, 1995), Lubke & De Villiers (1991), Parker-Nance et al. (1991), Talbot & Bate (1991), Bate & Dobkins (1992), Turner (1992), Boucher & Le Roux (1993), Taylor & Boucher (1993), Boucher & Rode (1995a, b, 1999), Britton & Jackelman (1995), Lubke et al. (1995, 1997), Gray (1997), Hertling (1997), Hertling & Lubke (1999a, b), Hesp & McLachlan (2000), Hoare et al. (2000), Ripley (2001), Barker et al. (2002).

AZd 4 Subtropical Seashore Vegetation

Dune Pioneers (Weisser 1978). A34 Strandveld p.p. (Acocks 1988). VT 4 Dune Thicket p.p. (Low & Rebelo 1996).

Distribution Eastern Cape and KwaZulu-Natal Provinces: Beaches, coastal dunes, dune slacks and coastal cliffs of the subtropical coasts of the Indian Ocean (from northeast of Kei Mouth in the Eastern Cape to the Mozambique border), the region includes South East, Transkei and KwaZulu-Natal coasts (*sensu* Tinley 1985, Lubke et al. 1997).

Vegetation & Landscape Features Open, grassy, herbaceous and to some extent also dwarf-shrubby, often dominated by a single species of pioneer character. Various plant communities reflect the age of the substrate and the natural disturbance regime (moving dunes), distance from the upper tidal mark and the exposure of dune slopes (leeward versus seaward).

Geology, Soils & Hydrology Recent coastal sandy sediments forming beaches and dunes, exposed to reworking by relentless wind and sea storms.

Climate Rainfall can occur any time during the year but with more in summer in the western part of the area (Kei Mouth region), with a pronounced summer precipitation peak along most of the northern coastal stretch. Overall MAP more than 1 000 mm. MAT of 20.3°C is indicative of a subtropical thermal regime. No frost occurs in the region. Very intensive solar irradiation enhanced by reflected albedo from the white dunes and the sea.

Important Taxa **Dunes & beaches**: Succulent Shrubs: *Phylohydrax carnosa* (d), *Scaevola plumieri* (d), *S. sericea*. Herbaceous Climbers: *Ipomoea pes-caprae* (d), *I. wightii*. Herbs: *Canavalia rosea* (d), *Gazania rigens* (d), *Chironia decumbens*, *Dasispermum suffruticosum*, *Gladiolus gueinzii*, *Helichrysum praecinctum*, *Launaea sarmentosa*, *Phyllopodium cuneifolium*, *Silene primuliflora*, *Tephrosia purpurea* subsp. *canescens*,

W.S Matthews

Figure 14.28 AZd 4 Subtropical Seashore Vegetation: *Scaevola plumieri* (Goodeniaceae) is a typical subtropical dune element forming dense populations from Maputaland (this view) as far west as Arniston (Western Cape).

Zaluzianskya maritima. Geophytic Herb: *Trachyandra divaricata*. Succulent Herb: *Arctotheca populifolia* (d). Graminoids: *Ficinia nodosa* (d), *Juncus kraussii* subsp. *kraussii* (d), *Sporobolus virginicus* (d), *Cyperus crassifolius*, *Imperata cylindrica*, *Stipagrostis zeyheri* subsp. *barbata*. **Cliffs**: Succulent Shrub: *Chenolea diffusa* (d). Herbs: *Chironia decumbens*, *Gazania rigens*. Succulent Herb: *Carpobrotus dimidiatus*. Graminoid: *Ficinia lateralis*.

Conservation Least threatened. Target 20%. Some 30% statutorily conserved in the Greater St Lucia Wetland Park as well as in the Richards Bay, Umlalazi, Amathikulu and Beachwood Mangroves Nature Reserves (all KwaZulu-Natal) and in the Mkambati Nature Reserve and Dwesa-Cwebe Wildlife Reserve & Marine Sanctuary (both Eastern Cape). Almost 10% already transformed by urban (largely tourism) development.

S.M. Proches

Figure 14.29 AZs 1 Algoa Dune Strandveld: Low strandveld thicket dominated by *Tetragonia decumbens* (Aizoaceae) and *Dimorphotheca fruticosa* (Asteraceae) on Bird Island in Algoa Bay near Port Elizabeth (Eastern Cape), supporting a large colony of jackass penguins (*Spheniscus demersus*).

Remarks The tropical coastal elements increase along the south-north gradient. The subtropical beaches and young dune systems of KwaZulu-Natal stand out through the occurrence of tropical floristic elements (*Canavalia, Phylohydrax, Ipomoea, Scaevola*).

References Edwards (1967), Moll & Pierce (1975), Campbell (1976), Weisser & Marques (1979), Donnelly & Pammenter (1983), Weisser & Müller (1983), Lubke et al. (1995, 1997), Hertling & Lubke (1999a, b), Smith (2001), Barker et al. (2002), L. Mucina (unpublished data).

Eastern Strandveld

AZs 1 Algoa Dune Strandveld

VT 34a Dense Strandveld Scrub p.p. (Acocks 1953). *Pterocelastrus tricuspidatus* Bushclumps, Dune Woodland (Taylor & Morris 1981). Subtropical Transitional Thicket p.p., *Cassine aethiopica-Cussonia thyrsiflora* South-East Dune Thicket (Cowling 1984). Dune Scrub and Thicket p.p. (Lubke & Van Wijk 1988). LR 4 Dune Thicket p.p. (Low & Rebelo 1996). STEP Algoa Dune Thicket, STEP Colcester Strandveld (Vlok & Euston-Brown 2002, Vlok et al. 2003).

Distribution Eastern Cape Province: Narrow coastal strip along the Indian Ocean seaboard from the mouth of the Tsitsikamma River to the Sundays River mouth.

Vegetation & Landscape Features Tall (up to 5 m) dense thickets on dunes mainly outside the influence of salt spray, dominated by stunted trees, shrubs (often armed with spines and thorns), abundant lianas and sparse herbaceous and grassy undergrowth.

Geology, Soils & Hydrology Aeolian dune sands of the Schelm Hoek Formation of the Algoa Group.

Climate Nonseasonal precipitation regime, with MAP approximately 680 mm, of which about 300 mm falls in summer (October–March) and 350 mm in winter (April–September). The mean daily maximum and minimum temperatures are 25.1°Cand 8.3°C for February and July, respectively. See also climate diagram for AZs 1 Algoa Dune Strandveld (Figure 14.3).

Important Taxa ([S]Stunted shrubby forms of trees) Succulent Tree: *Aloe africana* (d). Succulent Shrubs: *Cotyledon velutina*, *Lycium cinereum*, *Zygophyllum morgsana*. Tall Shrubs: *Azima tetracantha* (d), *Brachylaena discolor*[S] (d), *Chrysanthemoides monilifera* (d), *Cussonia thyrsiflora*[S] (d), *Euclea racemosa* subsp. *racemosa*[S] (d), *Maytenus procumbens* (d), *Mystroxylon aethiopicum*[S] (d), *Pterocelastrus tricuspidatus*[S] (d), *Rhus crenata* (d), *Schotia afra* var. *afra*[S] (d), *Scutia myrtina*[S] (d), *Sideroxylon inerme*[S] (d), *Tarchonanthus littoralis*[S] (d), *Canthium spinosum*[S], *Cassine peragua*[S], *Dovyalis rotundifolia*[S], *Euclea natalensis*[S], *E. racemosa* subsp. *macrophylla*, *Grewia occidentalis*, *Gymnosporia buxifolia*, *G. capitata*, *Nylandtia spinosa*, *Olea exasperata*, *Putterlickia pyracantha*, *Rhus glauca*, *R. pterota*, *Zanthoxylum capense*[S]. Low Shrubs: *Carissa bispinosa* (d), *Dimorphotheca fruticosa, Pelargonium suburbanum* subsp. *suburbanum*, *Robsonodendron maritimum*. Succulent Woody Climber: *Sarcostemma viminale*. Woody Climbers: *Rhoicissus digitata* (d), *Asparagus retrofractus*, *Solanum africanum*. Herbaceous Climbers: *Cynanchum natalitium* (d), *C. ellipticum*, *C. obtusifolium*, *Secamone alpini*. Succulent Herb: *Sansevieria hyacinthoides*. Graminoids: *Brachiaria chusqueoides* (d), *Panicum deustum*.

Endemic Taxa Succulent Shrub: *Cotyledon adscendens*. Tall Shrubs: *Gymnosporia elliptica*, *Rapanea gilliana*. Herb: *Lobelia zwartkopensis*. Geophytic Herb: *Brunsvigia litoralis*.

Conservation Least threatened. Target 20%. About 4% statutorily conserved in the Greater Addo Elephant National Park, Cape Recife, Sardinia Bay, The Island, Kromme River Mouth, Gamtoos River Mouth, Huisklip, Cape St Francis and Seal Point Nature Reserves as well as in the private Upe and Rebelsrus Nature Reserves, Thyspunt Natural Heritage Site and in the Seaview Game Park. More than 10% already transformed for cultivation, urban development and road building. Some of the dune systems suffer heavy infestation by *Acacia cyclops* and *A. saligna*, which are now being removed by the local Working for Water activities. Erosion very low (63%) and moderate (10%).

Remarks The structure and dynamics of this vegetation unit are similar to those of the thickets of FS 9 Groot Brak Dune Strandveld (see chapter on Fynbos in this book). However, the present unit differs from the latter in having a richer assemblage of woody species. It is somewhat surprising that forest vegetation is not dominant in this seemingly suitable climatic regime. This is probably because the substrate consists of aeo-

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Figure 14.30 AZs 1 Algoa Dune Strandveld: Typical coastal dune thickets on the coast of Algoa Bay east of Port Elizabeth (Eastern Cape).

Important Taxa ([S]Stunted shrubby forms of trees) Succulent Tree: *Aloe africana*. Succulent Shrubs: *Cotyledon orbiculata*, *Crassula nudicaulis*, *Delosperma ecklonis*, *D. litorale*. Tall Shrubs: *Brachylaena discolor*[S] (d), *Chrysanthemoides monilifera* (d), *Euclea undulata* (d), *Metalasia muricata* (d), *Pterocelastrus tricuspidatus* (d), *Sideroxylon inerme*[S] (d), *Azima tetracantha*, *Cassine peragua*[S], *Clausena anisata*[S], *Cordia caffra*, *Cussonia thyrsiflora*[S], *Diospyros dichrophylla*, *Euclea natalensis*[S], *E. racemosa* subsp. *macrophylla*, *Eugenia capensis*[S], *Grewia occidentalis*, *Gymnosporia buxifolia*, *Hippobromus pauciflorus*, *Maytenus procumbens*, *Mystroxylon aethiopicum*[S], *Plumbago auriculata*, *Putterlickia pyracantha*, *Rhus crenata*, *R. glauca*, *R. longispina*, *R. lucida*, *R. pterota*, *Robsonodendron eucleiforme*, *Schotia afra* var. *afra*[S], *Scutia myrtina*[S], *Tarchonanthus littoralis*[S], *Zanthoxylum capense*[S]. Low Shrubs: *Passerina rigida* (d), *Anthospermum littoreum*[S], *Asparagus capensis* var. *litoralis, Carissa bispinosa* subsp. *bispinosa*, *Helichrysum tereti-*

lian quaternary sands, salt-laden winds are prevalent in this region and because fires may periodically occur here (Vlok & Euston-Brown 2002).

References Taylor & Morris (1981), Olivier (1983), Cowling (1984), Cowling & Pierce (1985), Taylor & Boucher (1993), Vlok & Euston-Brown (2002), Vlok et al. (2003).

AZs 2 Albany Dune Strandveld

Psammophilous Macchia and Littoral Scrub (Dyer 1937). VT2 Alexandria Forest p.p., VT1 Coastal Forest and Thornveld p.p. (Acocks 1953). *Cassine aethiopica–Schotia afra* Alexandria Dune Thicket (Cowling 1984). Dune scrub and thicket p.p. (Lubke & Van Wijk 1988). LR 4 Dune Thicket p.p. (Low & Rebelo 1996). STEP Albany Dune Thicket (Vlok et al. 2002). For further synonyms see Avis & Lubke (1996, p. 242).

Distribution Eastern Cape Province: A narrow coastal strip of the Indian Ocean extending from the Sundays River to south of Kei Mouth.

Vegetation & Landscape Features Very dense shrubby thicket composed of 2–4 m high, mostly sclerophyllous shrubs accompanied by several woody and herbaceous vines, and with a sparse grassy understorey. This unit also includes low (wind-sheared and salt-sprayed), dense thickets found on seaward slopes of the coastal dune cordons and rocky headlands (coastal cliffs). The occurrence of bulbous geophytes and succulent herbs is an important feature of this vegetation unit.

Geology, Soils & Hydrology Dune systems of the Schelm Hoek Formation, which also consists of dune sands in which shell material and calcrete lenses occasionally occur, as well as older Algoa Group calcareous sandstones and shallow marine deposits.

Climate Rainfall can occur any time of the year (but with most in summer), but the probability of rain is the highest in March and October (slight bimodality). MAP slightly higher than 700 mm. The temperature regime is ameliorated, with the mean daily maximum and minimum temperatures being 26.4°C and 8.8°C for February and July, respectively. The unit lies in a broad transition including warm-temperate and subtropical regions. Local salt-laden sea winds constitute a serious stress factor. See also climate diagram for AZs 2 Albany Dune Strandveld (Figure 14.3).

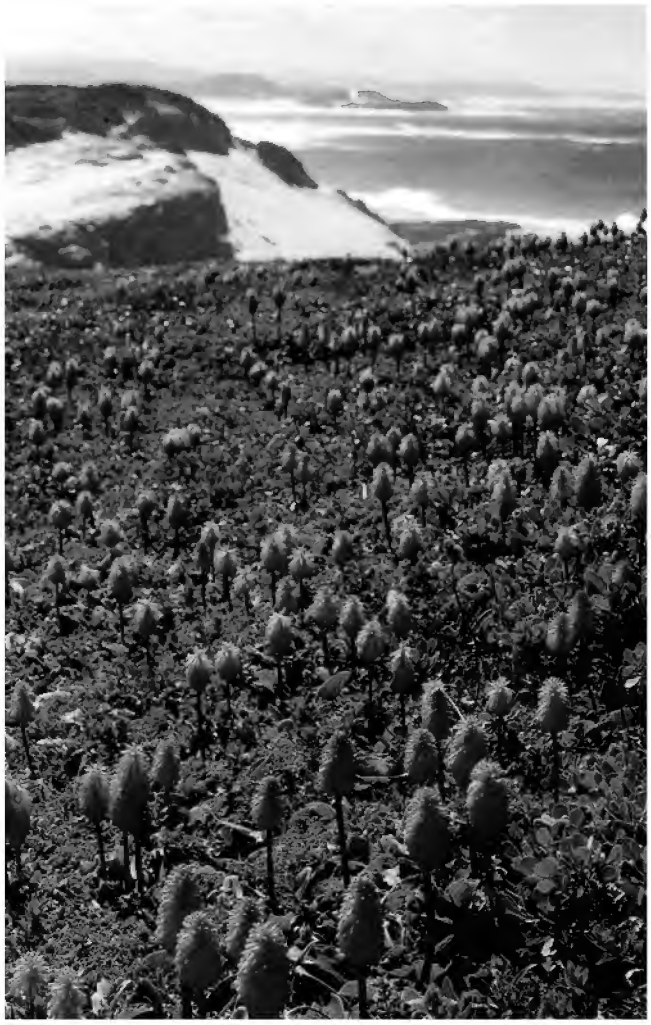

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Figure 14.31 AZs 2 Albany Dune Strandveld: Spring display of bulbous *Veltheimia bracteata* (Hyacinthaceae) in a wind-sheared *Pterocelastrus tricuspidatus* and *Robsonodendron maritimum* (both Celastraceae) coastal thicket on an aeolinite headland at the Diaz Cross site between Boknes and Kenton-on-Sea (Eastern Cape).

folium, *Lauridia tetragona*, *Pavetta revoluta*, *Psoralea repens*, *Rhoiacarpos capensis*, *Robsonodendron maritimum*, *Salvia africana-lutea*, *Senecio burchellii*. Semiparasitic Shrub: *Osyris compressa*. Succulent Woody Climber: *Sarcostemma viminale*. Woody Climbers: *Asparagus asparagoides*, *A. racemosus*, *Capparis sepiaria*, *Rhoicissus digitata*. Herbaceous Succulent Climber: *Senecio angulatus*. Herbaceous Climbers: *Astephanus marginatus*, *Cynanchum ellipticum*, *C. natalitium*, *C. obtusifolium*, *Kedrostis nana*, *Senecio deltoideus*. Herbaceous Parasitic Climber: *Cassytha filiformis*. Herb: *Felicia erigeroides*. Geophytic Herbs: *Haemanthus albiflos* (d), *Veltheimia bracteata* (d), *Androcymbium longipes*, *Bonatea speciosa*, *Bulbine frutescens*, *Chasmanthe aethiopica*, *Dietes iridioides*, *Gladiolus floribundus*, *Massonia echinata*, *Sansevieria hyacinthoides*, *Trachyandra revoluta*. Succulent Herbs: *Carpobrotus deliciosus*, *C. edulis*, *Crassula cotyledonis*, *Gasteria acinacifolia*, *G. croucheri*. Graminoids: *Stenotaphrum secundatum* (d), *Brachiaria chusqueoides*, *Panicum deustum*.

Conservation Least threatened. Target 20%. Some 25% statutorily conserved in the Greater Addo Elephant National Park, Gulu, Christmas Vale, Cape Morgan, Cintsa, Cove Rock, Bluebend and Sunshine Coast Nature Reserves as well as in private conservation areas such as the Glendour and Kasouga Farm Natural Heritage Sites and Waterloo Bay Forest Reserve. Alien Australian acacias (*Acacia cyclops, A. saligna, A. longifolia*) have invaded large stretches of the coastal thicket and are dominant in places. *Lagurus ovatus* and species of *Lolium* occur in disturbed patches of this coastal thicket. At present these plants are targeted for eradication by the Working for Water Programme of DWAF. Some 8% transformed for urban development and cultivation. Erosion very low (26%), moderate (22%), high (14%) and low (11%).

Remarks Most of the woody species present in the Algoa Dune Strandveld vegetation also occur in AZs 2 Albany Dune Strandveld, but here the species richness is enhanced by several subtropical elements such as *Pavetta revoluta* and *Phoenix reclinata*—taxa that reach their southernmost distribution here. The presence of species such as *Euphorbia triangularis, Plumbago auriculata* and *Scutia myrtina* in this unit indicates a direct relationship with the neighbouring Albany Thicket. This relationship may well indicate that the thickets of the Albany Dune Strandveld have long been a precursor of climax forest vegetation, probably not dissimilar to those of the present Alexandria Forest.

References Dyer (1937), Martin & Noel (1960), Comins (1962), Lubke (1983), Burns (1986), La Cock (1986), Young (1987), Lubke & De Villiers (1991), Talbot & Bate (1991), Weisser & Cooper (1993), Avis & Lubke (1996), Vlok & Euston-Brown (2002), Vlok et al. (2003).

AZs 3 Subtropical Dune Thicket

Passerina rigida Low Scrub, Seeward, Coastal Thicket and Low Forest (Weisser 1978). Closed Dune Scrub, Open Dune Scrub (Ward 1980). Dune Thicket (Weisser et al. 1992a). STEP Transfish Dune Thicket (Vlok & Euston-Brown 2002, Vlok et al. 2003).

Distribution Eastern Cape and KwaZulu-Natal Provinces (further north also in Mozambique): Coastal dune cordons along the subtropical coasts of the Indian Ocean between Kei Mouth and the KwaZulu-Natal/Mozambique international border.

Vegetation & Landscape Features Very dense shrubby thickets of spiny shrubs (up to 4 m), large-leaved megaherbs (*Strelitzia nicolai*), dwarfed trees (species of *Allophylus, Apodytes, Mimusops*), abundant vines, and with poorly developed undergrowth due to the shading effect of the closed canopy. Dwarf coastal dune shrublands on exposed, wind-blasted and salt-sprayed dune slopes bordering on tall thickets are also included here.

Geology, Soils & Hydrology Recent dunes overlying calcretes as well as Maputaland Group calcareous sandstones and shallow marine deposits.

Climate Characterised by relatively high MAP (1 028 mm) and a high probability of rain any time of the year (with pronounced higher rainfall in all seasons, except for the winter months of June and July. Subtropical thermal regime with MAT 19.0°C and no incidence of frost. See also climate diagram for AZs 3 Subtropical Dune Thicket (Figure 14.3).

Important Taxa ([S]Stunted shrubby forms of trees) Succulent Tree: *Euphorbia triangularis*. Small Trees: *Encephalartos altensteinii*, *Phoenix reclinata*. Tall Shrubs: *Brachylaena discolor*[S] (d), *Chrysanthemoides monilifera* (d), *Acokanthera oblongifolia*[S], *Allophylus natalensis*[S], *Apodytes dimidiata* subsp. *dimidiata*[S], *Azima tetracantha*, *Canthium inerme*[S], *C. spinosum*[S], *Cordia caffra*, *Deinbollia oblongifolia*[S], *Diospyros rotundifolia*[S], *Dodonaea viscosa*, *Euclea natalensis* subsp. *rotundifolia*[S], *E. racemosa* subsp. *macrophylla*, *Eugenia capensis*[S], *Grewia occidentalis*, *Gymnosporia buxifolia*, *G. nemorosa*, *Harpephyllum caffrum*[S], *Hyperacanthus amoenus*, *Maytenus procumbens*, *Mimusops caffra*[S], *Monanthotaxis caffra*[S], *Mystroxylon aethiopicum*[S], *Psychotria capensis*, *Psydrax obovata* subsp. *obovata*[S], *Putterlickia pyracantha*, *P. verrucosa*, *Rhus glauca*, *R. lucida*, *R. nebulosa*, *Rothmannia globosa*[S], *Scutia myrtina*[S], *Sideroxylon inerme*[S], *Tarchonanthus littoralis*[S], *Tricalysia sonderana*[S], *Zanthoxylum capense*[S]. Low Shrubs: *Carissa bispinosa* subsp. *bispinosa*, *C. macrocarpa*, *Helichrysum kraussii*, *Passerina rigida*, *Pavetta revoluta*, *Robsonodendron marit-*

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Figure 14.32 AZs 2 Albany Dune Strandveld: Wind-sheared coastal thickets on a dune at Kenton-on-Sea (Eastern Cape), with *Pterocelastrus tricuspidatus* and *Robsonodendron maritimum* (both Celastraceae) dominant.

imum. Soft Shrub: *Isoglossa woodii*. Succulent Woody Climber: *Cyphostemma flaviflorum*. Woody Climbers: *Adenopodia spicata*, *Coptosperma littorale*, *Rhoicissus digitata*, *R. rhomboidea*, *Tragia glabrata* var. *glabrata*. Herbaceous Climbers: *Cynanchum natalitium*, *C. obtusifolium*, *Gloriosa superba*, *Ipomoea ficifolia*, *I. wightii*. Herbs: *Asystasia gangetica*, *Lobelia pinifolia*, *Rubia cordifolia*. Megaherb: *Strelitzia nicolai* (d). Geophytic Herbs: *Crocosmia aurea*, *Microsorum scolopendria*, *Scadoxus puniceus*. Parasitic Herb: *Hyobanche fulleri*. Graminoids: *Stenotaphrum secundatum* (d), *Panicum deustum*.

Biogeographically Important Taxon (shared with Mascarene Islands and Madagascar) Succulent Shrub: *Lycium mascarenense*.

Endemic Taxa Succulent Shrub: *Aloe thraskii* (d). Low Shrub: *Sophora inhambanensis*.

Conservation Least threatened. Target 20%. About 27% statutorily conserved in the Greater St Lucia Wetland Park as well as in the Richards Bay, Umlalazi, Amathikulu (all KwaZulu-Natal), Bosbokstrand, Kwelera, Cape Henderson and Cape Morgan Nature Reserves. Unknown percentage transformed by urban sprawl and especially by coastal heavy-mineral mining. Aliens such as *Chromolaena odorata, Lantana camara* and a species of *Pereskia* occur as serious infestations in places. Erosion very low (12%), other erosion categories only at low values.

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Figure 14.33 AZs 3 Subtropical Dune Thicket: *Aloe thraskii* (Asphodelaceae), a tall succulent that can tolerate high levels of salt in the soil and a typical element of subtropical dune thickets (Amanzimtoti south of Durban, KwaZulu-Natal).

Remarks There is a clear floristic link between this vegetation unit and the Eastern Cape Dune Forest in the southern parts of the distribution area and KwaZulu-Natal Dune Forest (for concept and terminology see Von Maltitz et al. 2003 and Geldenhuys & Mucina 2005) in the northern parts of the area. Besides floristic differences, the most striking difference lies in the vegetation structure and age of dunes populated by the respective types.

References Edwards (1967), Moll & Pierce (1975), Weisser (1978), Ward (1980), Weisser et al. (1982, 1992a), Donnelly & Pammenter (1983), MacDevette (1989a, b), Weisser & Cooper (1993), Lubbe (1997), Boucher (1998b), Smith (2001), Vlok & Euston-Brown (2002), Vlok et al. (2003).

9. Credits

The concept of the coastal vegetation units were coined by L. Mucina and M.C. Rutherford with the assistance of the authors of the particular descriptions (see below). L.W. Powrie contributed considerably to the precise delimitation of the vegetation units by using satellite imagery of the coastal regions. The introductory text is a team effort by L. Mucina (all sections), I. Knevel (sections on sand dunes), J.B. Adams and T.G. Bornman (sections on estuaries), J.J. Bolton and R.J. Anderson (sections on algal beds) and J.H.J. van der Merwe (section on origins of the coastal features). The descriptions of all units (except for AZm 1) were written by L. Mucina. He was assisted by A. le Roux (units AZe 2, AZd 1 and 2), J.A.M. Janssen (AZe 2), J.B. Adams (AZd 1 and 2) and T.G. Bornman (AZd 2). The data on conservation (status and targets) were provided by the team spearheading the National Spatial Biodiversity Assessment at SANBI (in particular by M. Rouget, P.G. Desmet and others—see also Chapters 16 and 17 in this book). The other relevant sections (alien infestation, erosion, conservation areas) were prepared by L.W. Powrie using various GIS sources (see Chapter 2 for further details). Figure 14.2 was reproduced with courtesy of American Meteorological Society, Figure 14.8 from Tinley (1985) with kind permission of the CSIR. Figure 14.6 was prepared by J.B. Adams and Figure 14.17 by L. Mucina. Table 14.1 was compiled by I. Knevel and L. Mucina, Table 14.2 and 14.4 by J.B. Adams and Table 14.3 by L. Mucina. The maps of distribution of the vegetation units (Figure 14.18) were prepared by L. Mucina and L.W. Powrie. M.C. Rutherford and L.W. Powrie provided all climate data and the climate diagrams (Figure 14.12). M. Rouget and others within the SANBI Directorate of Biodiversity Programmes, Policy and Planning provided the quantitative information on conservation status, targets and areas transformed through road construction for each vegetation unit. R.A. Ward kindly checked and corrected the sections on geology. All photographs were taken by L. Mucina, except for two which were kindly supplied by W.S. Matthews (the opening photograph) and Ş.M. Procheş. The list of references was compiled and collated by L. Mucina using own as well as co-authors' sources.

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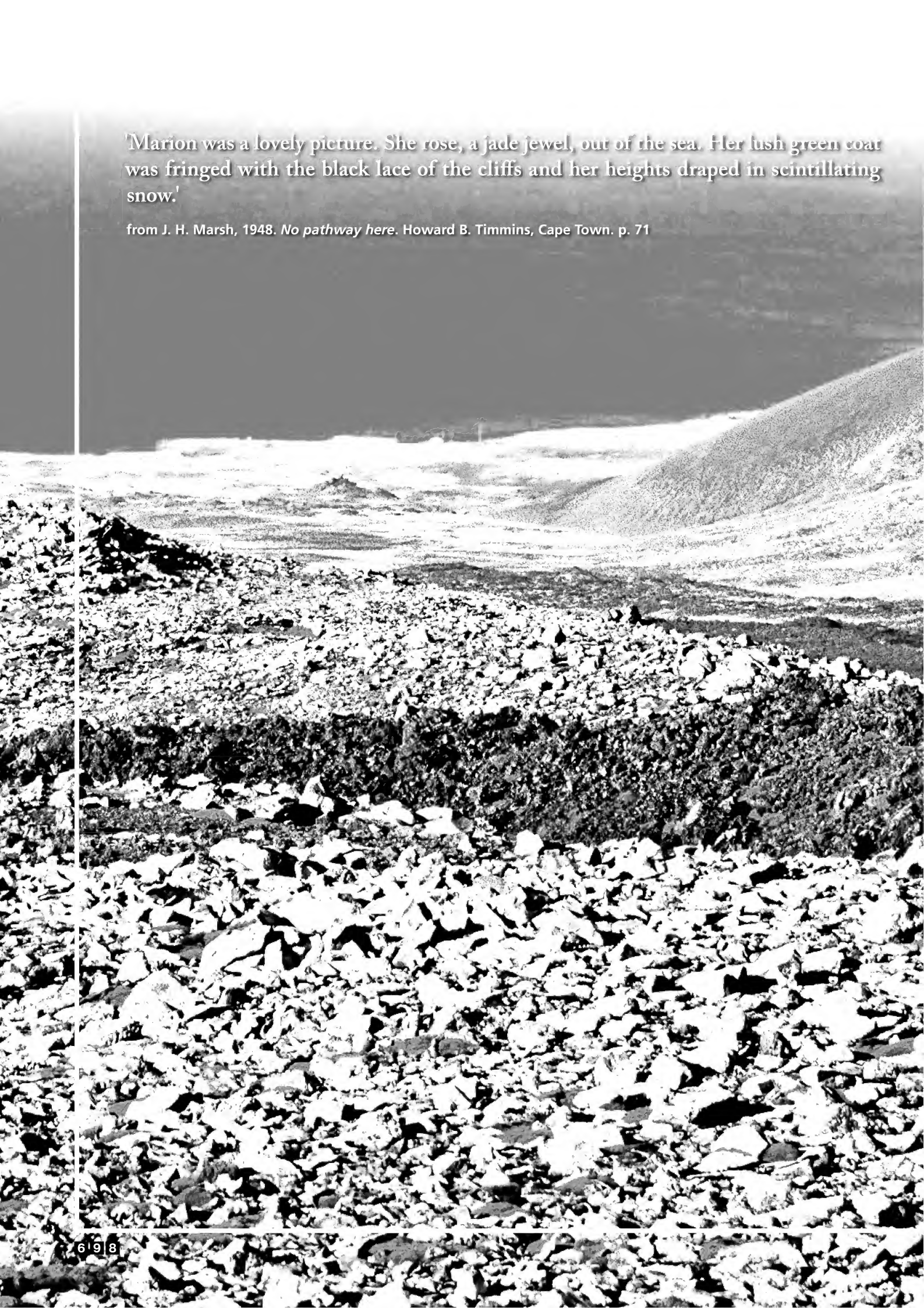
'Marion was a lovely picture. She rose, a jade jewel, out of the sea. Her lush green coat was fringed with the black lace of the cliffs and her heights draped in scintillating snow.'

from J. H. Marsh, 1948. *No pathway here*. Howard B. Timmins, Cape Town. p. 71



Vegetation of Subantarctic Marion and Prince Edward Islands

15

Valdon R. Smith and Ladislav Mucina

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ST 1 Subantarctic Coastal Vegetation	715
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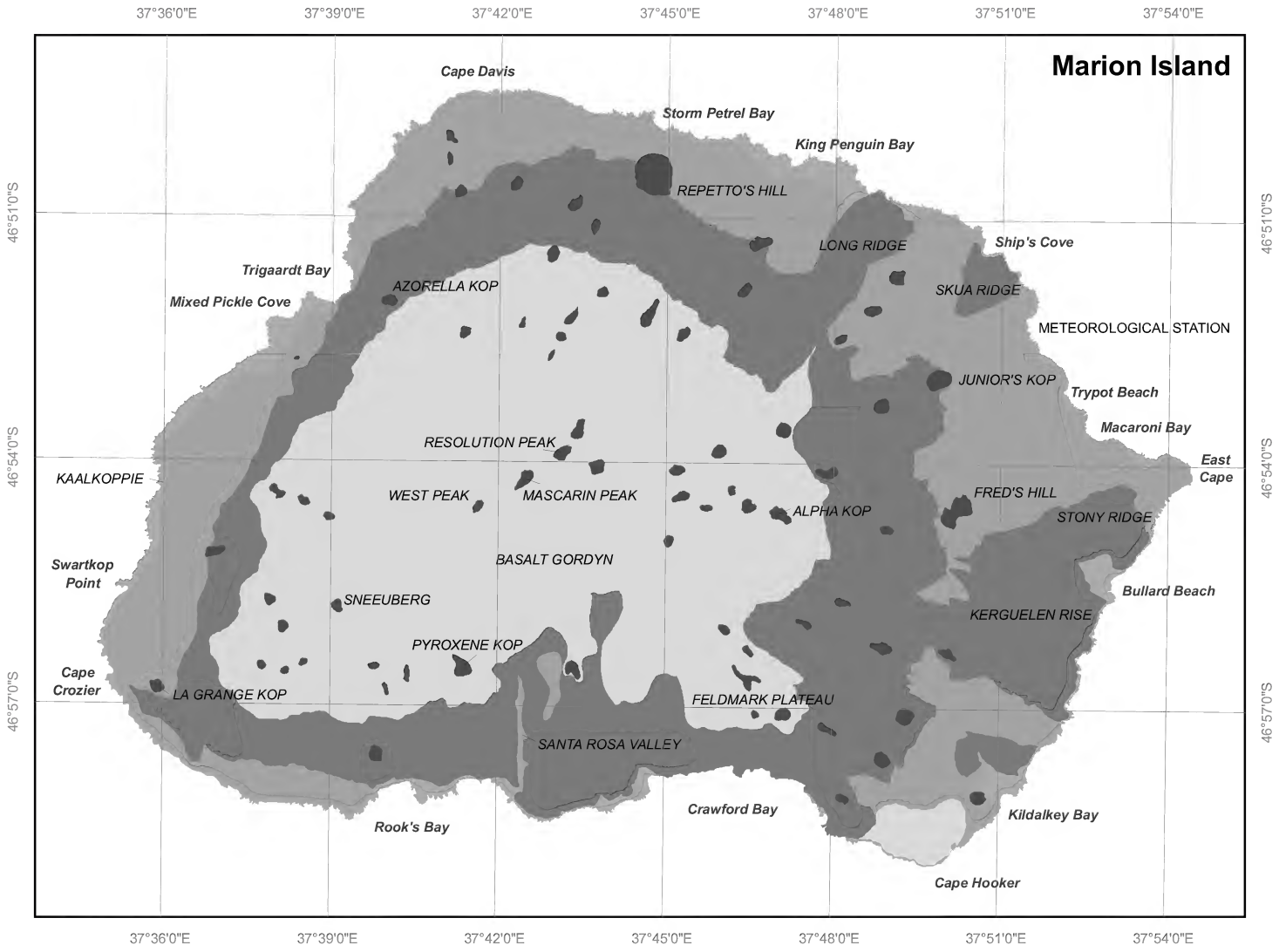
Figure 15.1 Fellfield vegetation with *Azorella selago* on Marion Island. In the foreground a narrow tongue of Holocene black lava extends over a Pleistocene grey lava flow. In the background, 4 km away, is the meteorological station surrounded by a mosaic of mire, slope and fellfield. The cinder cone on the right is Junior's Kop.

V.R. Smith

Prince Edward Islands



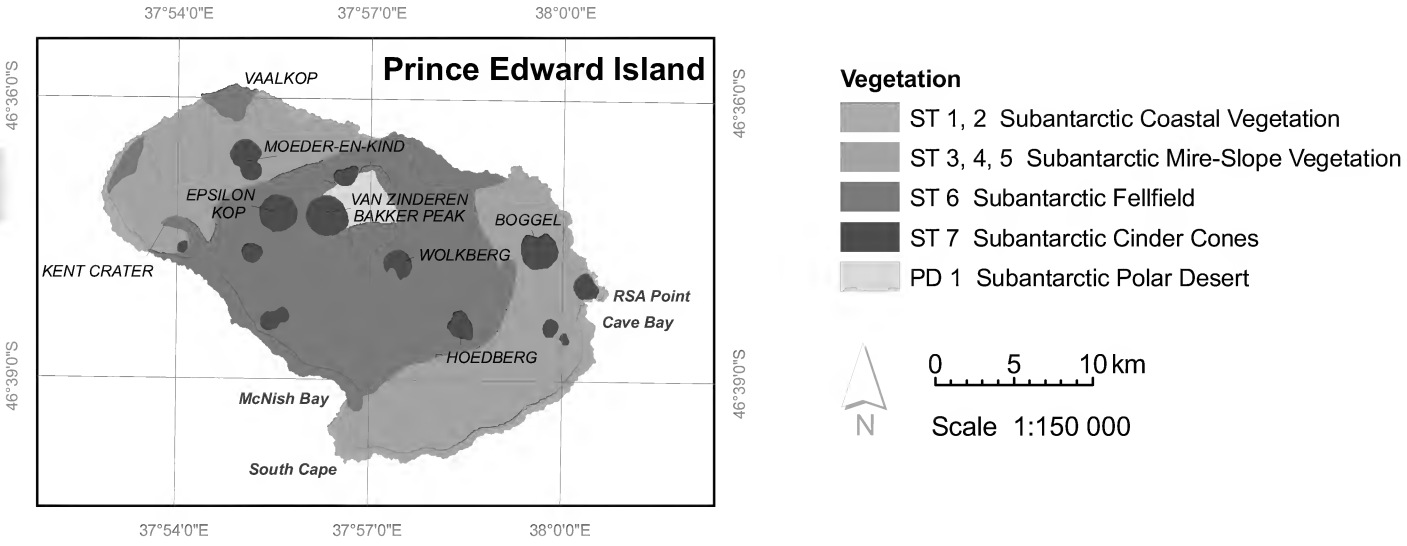


Figure 15.2 Vegetation maps of the Prince Edward Islands.

1. Introduction

South Africa possesses two subantarctic islands—Marion Island (46° 54′ S, 37° 45′ E) and Prince Edward Island (46° 38′ S, 37° 57′ E) (Figure 15.3). Together they are known as The Prince Edward Islands. Marion Island was annexed by South Africa on 29 December 1947 and Prince Edward Island on 4 January 1948. The annexations became effective with the passing by Parliament of the Prince Edward Islands Act (43) of October 1948. Marion Island has been occupied permanently by South African research and logistic personnel since February 1948. There is no permanent occupation of Prince Edward Island.

2. The Subantarctic Region and Tundra

The term subantarctic refers to various regions of the Southern Ocean, depending upon whether it is used in an oceanographic, limnological or biological context. Even within these disciplines, workers have considered different numbers of islands and island groups as subantarctic. Oceanographers generally define the subantarctic region as the zone of waters between the Antarctic and Subtropical Convergences (Deacon 1960). The latitudinal distributions of those organisms dependent entirely upon the sea for their existence seem to follow these boundaries quite well but the limits of the main types of terrestrial vegetation (Wace 1965), insect fauna (Gressitt 1970) and avifauna (Barrat & Mougin 1974) do not coincide with them so closely.

Botanists have generally preferred to define the subantarctic region on plant physiognomic, vegetation structure or climatic criteria. For instance, Wace (1960, 1965) proposed delimiting the subantarctic region as the area south of the southern limit of tree or shrub growth (distinguishing it from the cool temperate zone) and north of the southern limit of closed phanerogamic vegetation (delimiting it from the maritime or low-ant-

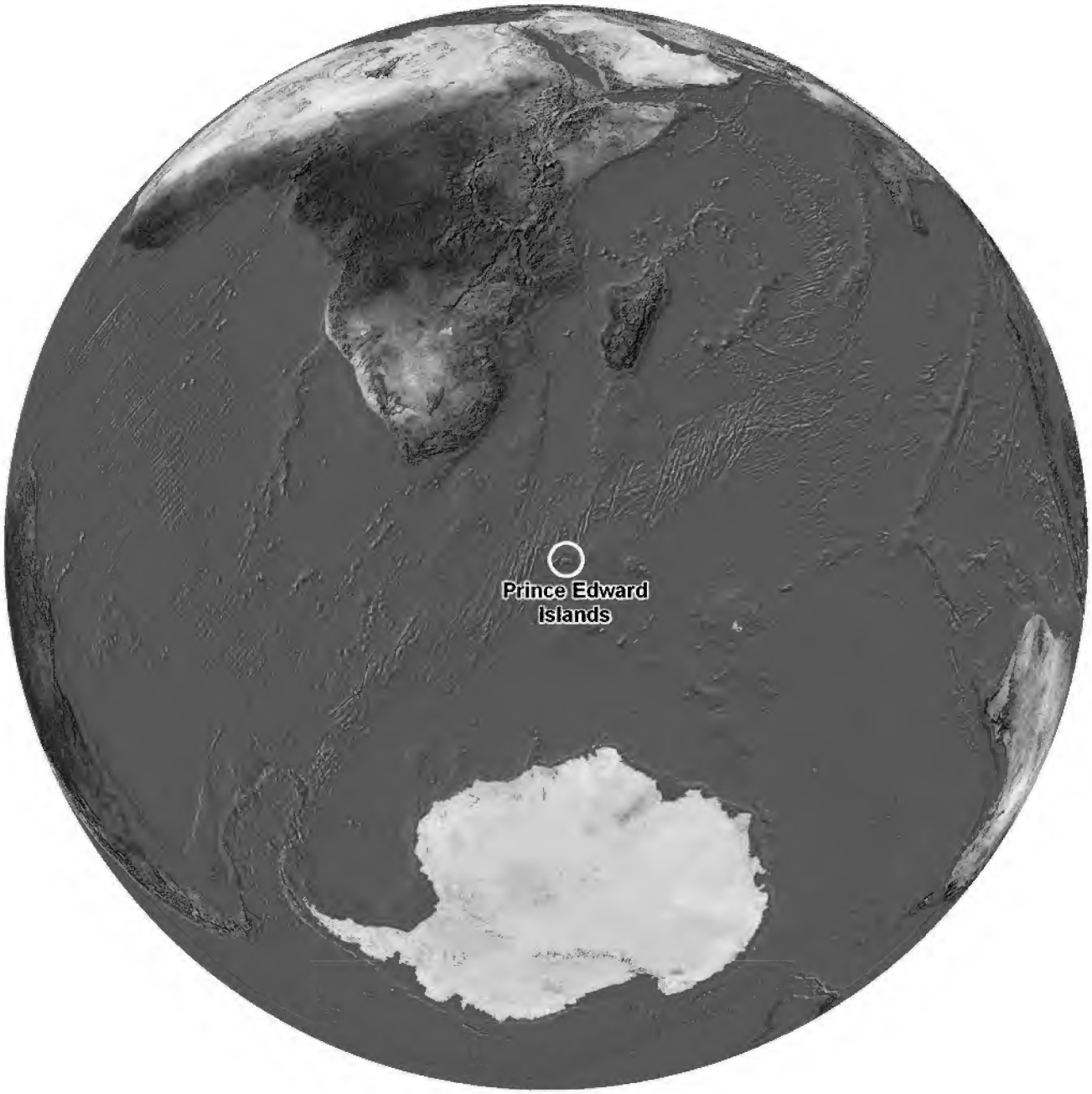


Figure 15.3 Position of the Prince Edward Islands in Southern Ocean, between Antarctica and Africa (courtesy of I. Meiklejohn).

arctic to the south). In Wace's scheme the following terrestrial plant communities were considered to characterise the subantarctic vegetation zone:

- Closed herbfield communities in which large-leaved perennial herbs are conspicuous.
- Communities of pedestal-forming tussock grasses, especially on the coast.
- Soligenous mires in which the peat-forming plants are bryophytes and sedges (not sphagna or cushion-forming vascular plants).
- Fellfield or wind-desert communities composed of flowering plants with very compact mat or cushion growth forms.

Although Wace (1965) considered this classification to be independent of climatic, geological or other environmental data, the delimitation boundaries correspond closely to those of the climatological classification of Holdgate (1964) based on the range of mean monthly temperatures. In that classification the subantarctic zone is characterised by the absence of temperatures warmer than 8.5°C, considered to preclude the occurrence of trees (Pearsall 1950, Holdgate 1964).

Holdgate (1970, 1977) proposed a more definitive classification of the southern subpolar zone that, with some modification, has been widely accepted (Block 1984, Pickard & Seppelt 1984, Clark & Dingwall 1985, Bonner & Lewis Smith 1985, Smith & Lewis Smith 1987). The geographic, climatic and biotic characteristics of the various subdivisions (regions and provinces) of the zone are outlined by Lewis Smith (1984). The subantarctic region comprises six islands or island groups (South Georgia, Macquarie, Heard and McDonald, Kerguélen, the Crozets, Marion and Prince Edward), all situated within a few degrees latitude of the Antarctic Convergence. Because of the cold Bouvet Current that originates in the Weddell Sea, the Convergence extends farther north in the Indian Ocean so that relatively low-latitude islands such as Marion, Prince Edward and Îles Crozet are included as subantarctic, even though they are farther north than the islands of the New Zealand continental shelf (Campbell, Antipodes, Auckland, Snares). These latter, because they possess a well-developed shrub and/or low tree vegetation, are considered to belong to the cool temperate zone, together with the Tristan da Cunha-Gough Island group, Île Amsterdam, Île Saint-Paul, Falkland Islands and southern Tierra de Fuego. At the other extreme, Bouvetoya and the South Sandwich Islands are sometimes included in the subantarctic region (Walton 1985), although they are more typically maritime antarctic, like the South Orkney Islands and South Shetland Islands (Lewis Smith 1984). Alternative classifications of mid- to high-latitude regions of the southern hemisphere are discussed by Smith & Lewis Smith (1987).

Tundra is usually defined as areas where the average annual temperature is below 0°C and permafrost occurs. It has also been used when referring to areas where the temperature is too low, and precipitation and wind too great, for a natural forest vegetation to develop. For example, oceanic moorland, some mountainous regions and two subantarctic islands, all of which have somewhat higher annual mean temperatures than tundra *sensu stricto*, were included in the Tundra Biome Study of the International Biological Programme (Rosswall & Heal 1975, Bliss et al. 1981). In fact, subantarctic vegetation has traditionally been decribed as tundra. Very few taxonomic affinities exist between the biotas of subantarctic islands and the Arctic or Subarctic, but there are several physiognomic similarities in their vegetations. In order to highlight the unique nature of subantarctic ecosystems, it is useful to compare terrestrial areas of the Subantarctic briefly with those of the Antarctic and also with those of the Subarctic.

Owing to the overwhelming influence of the ocean, the subantarctic region exhibits a very limited annual temperature range, so that winters are warmer and summers cooler than continental subpolar sites of the northern hemisphere (e.g. see Figure 2 in French & Smith 1985). Thus, while the subarctic environment may be considered to be a less severe version of that of the Arctic, the difference between subantarctic and antarctic conditions was described by Rudmose-Brown (1928) as follows:

'The term subantarctic is justified rather by proximity to the Antarctic than by any real approximation to Antarctic conditions. The truly Antarctic climate is typically continental, in contrast to the climate of the subantarctic islands, which is essentially oceanic, and in most respects cool-temperate, rather than polar.'

This important difference between subantarctic and subarctic regions is due to the unequal proportion of land and sea in the two zones (Di Castri et al. 1970). While large continental masses of North America, Asia and Europe belong to the subarctic region, subantarctic terrestrial areas are very discontinuous. This has a series of climatic, biogeographical and ecological consequences, some of which have been demonstrated by French (1974, 1981) and French & Smith (1985) in multivariate comparisons of subantarctic and maritime antarctic terrestrial ecosystems with northern hemisphere tundra and tundra-like ecosystems (ranging from high arctic to cool-temperate and temperate alpine). The comparisons, based on climate, soil chemical composition and vegetation, emphasise the effects of the extreme oceanity and the influence of sea spray and animal manuring on the ecosystems of the southern hemisphere subpolar sites. They clearly show that subarctic ecosystems are generally less severe forms of arctic ones, and decreasing latitude leads to increasingly milder environments with no great changes overall in continentality. In contrast, the Subantarctic combines elements from the extremes of the range of northern hemisphere tundra (i.e. high-arctic and cool-temperate oceanic) with its own peculiar features, e.g. geographical isolation, wind exposure, high rainfall, small seasonal temperature range and the strong influence of the marine ecosystem (especially of seals, seabirds and salt spray) to produce ecosystems that are qualitatively different from both subarctic systems and the continental antarctic regions to which they are geographically closest.

The isolation of terrestrial subantarctic ecosystems and, in most cases, their relatively recent origin causes their floras to be species-poor, in contrast to most subarctic and low arctic areas of the northern hemisphere. Despite this, the multivariate analyses done by French & Smith (1985) show that the southern hemisphere sites exhibit almost the full range of vegetation types found in the northern hemisphere. Cluster analyses of climates and soils link the Southern Ocean islands with northern hemisphere sites at higher latitudes, indicating the effect of the Antarctic continent on the climate of the southern islands. Climatic wetness, together with strong winds, applies a significant chill factor so that the vegetation of the southern islands resembles that of much higher latitudes in the northern hemisphere. The latitudinal difference between northern and southern sites with equivalent vegetation types is as much as 20 or even 30 degrees. The range of soil nutrient levels at the southern hemisphere subpolar sites is approximately equal to that at the northern hemisphere subpolar sites; however, in the southern sites soil nutrient levels are inversely related to climatic severity, while in the north the reverse is true. The two most

important causes of these opposed trends are the relative geological and pedological ages of the sites (younger sites tend to be at higher latitudes in the north but at lower latitudes in the south) and the much greater effects of sea-based vertebrates on the southern islands.

Subantarctic islands are geologically comparatively young compared with land masses of the northern hemisphere subpolar region. The islands are also extremely remote, mostly more than 1 500 km from the nearest continent. Their indigenous biota has been established by the slow process of immigration and colonisation over large expanses of ocean, so that the floras and faunas of the islands exhibit low diversity. For instance, Lewis Smith (1984) listed 72 vascular plant species indigenous to the Subantarctic, whereas the Canadian Arctic Archipelago, a climatically far more extreme region and ca. 25° of latitude nearer the Pole than the Subantarctic, has more than 340 indigenous vascular plant species (Porsild 1964). Several vascular plant species are endemic to the Subantarctic, but occur on more than one island or island group (Walton 1985). Only four species are endemic to one island or island group (Lewis Smith 1984). The low degree of endemism in the vascular floras of the subantarctic islands, compared with those of the older cool-temperate islands to the north—for instance 31% of the 200 vascular species on the New Zealand shelf islands are endemic (Devine 1984)—probably results from the relatively short time available for the evolution of new species since the last glaciations. However, despite their floristic poverty, subantarctic islands exhibit almost the full range of vegetation types found in tundra (*sensu* I.B.P.) of the northern hemisphere (French & Smith 1985). Perhaps the most notable exception is that lichen-dominated communities similar to those found in tundra of the northern hemisphere do not occur.

3. Geography of Marion and Prince Edward Islands

3.1 Climate

The Prince Edward Islands are amongst the warmest of the subantarctic islands; only the Crozet Archipelago is as warm. Mean monthly and mean annual temperature, precipitation and sunshine at Marion Island are shown in Table 1. Other climatic data are depicted in Figure 15.4. The surrounding Southern Ocean causes the islands' climate to be thermally stable. The difference between mean temperature of the coldest and warmest months is only 4.1°C and the mean diurnal temperature variation is only 1.9°C. Precipitation is high, more or less equally distributed throughout the year and, although snow and ice rain do occur, is mostly in the form of rain at the coast. The high precipitation is associated with a high incidence of cloudiness and infrequent direct sunshine.

Despite the thermal stability of the islands, annual mean temperature has increased steadily in the past three decades and six of the last seven years (1996 to 2002) were the warmest on record. Since 1969 air temperature has increased, on average, by 0.04°C per year (Smith 2002) and warming has occurred in all months except June. The highest rate of warming has been from late austral winter to midsummer (September to January), and the lowest in late summer, autumn and winter (February to August), with the notable exception of April which showed the greatest warming of all the months. Recently, Mélice et al. (2003) showed that annual mean sea temperature around Marion Island has risen, on average, by 0.04°C per year since the 1970s, the same as the mean increase in air temperature. Similar air temperature increases have been reported for three other subantarctic islands (for Macquarie Island by Adamson et al. 1988, Kerguélen Island by Frenot et al. 1997 and Heard Island by Budd 2000).

Annual precipitation has decreased since the mid-1960s, so that the 1990s was the driest of the five decades that precipitation has been measured on the island. All months except October have become drier. Interannual variability in annual total sunshine hours is irregular, but a significant proportion of it can be ascribed to an average increase of 3.3 hours per year between 1951 and 2002. Hours of sunshine increased for all months in that period.

The radiation, air and sea temperature increases, and the precipitation decrease, on Marion Island might be associated with changing atmospheric circulation patterns (perhaps also changing oceanic circulation). Smith & Steenkamp (1990) pro-

Table 15.1 Average monthly and annual air temperature, precipitation and sunshine for Marion Island. Values are derived from data supplied by the South African Weather Bureau and were obtained from measurements made between 1949 and 2002 at the Meteorological Station which is about 25 metres above sea level.

	Temperature (°C)			Precipitation (mm)			Sunshine (hours day^{-1})		
	Ave. mean	Min. mean	Max. mean	Ave. total	Min. total	Max. total	Ave. mean	Min. mean	Max. mean
Jan	7.3	5.8	9.1	209	90	350	5.1	3.4	6.4
Feb	7.8	6.2	9.3	188	73	333	4.8	3.8	6.3
Mar	7.5	6.5	8.9	199	52	397	3.8	2.8	5.6
Apr	6.4	4.5	8.2	210	125	363	3.1	1.7	4.3
May	5.3	3.7	7.1	222	100	428	2.5	1.4	3.3
Jun	4.6	2.8	6.0	203	91	461	1.9	0.9	2.8
Jul	4.1	2.6	5.9	196	98	319	2.1	1.3	2.9
Aug	3.7	2.1	4.7	180	98	250	2.8	1.5	4.3
Sep	3.8	2.3	5.3	183	101	360	3.4	2.4	4.6
Oct	4.6	3.4	6.2	171	75	288	4.5	2.8	7.2
Nov	5.5	4.1	7.7	172	48	316	5.3	3.2	6.9
Dec	6.4	4.7	8.2	200	73	302	5.2	3.8	6.7
Year	5.6	4.8	6.6	2327	1861	2992	3.7	3.2	4.1

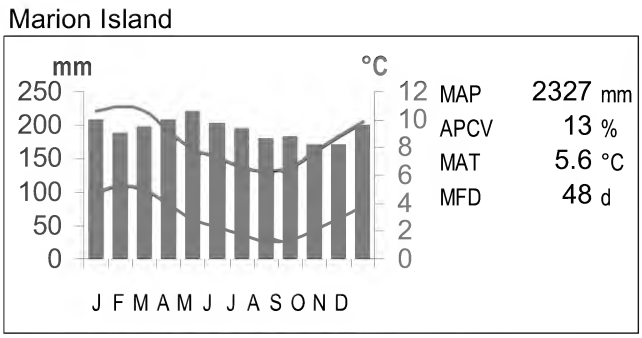


Figure 15.4 Climate diagram of the weather station Marion. The graph shows mean monthly precipitation (blue bars), and mean of daily minimum and maximum temperatures for each month (red lines). MAP: Mean Annual Precipitation. APCV: Annual Precipitation Coefficient of Variation. MAT: Mean Annual Temperature. MFD: Mean Frost Days per year.

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Figure 15.5 Landscapes of Marion Island: A view from the Meteorological Station across straw-coloured mires (dry *Agrostis magellanica*), dark green belt of fernbrakes towards the snow-clad slopes of the central mountains carrying Polar Desert on the summits.

posed a model whereby interannual differences in radiation, temperature and precipitation can be explained by the positions of cyclone tracks relative to the island. Approximately 100 cyclones pass the island in a year. In warmer years the cyclonic centres pass, on average, further to the south of the island so that it spends a longer period subjected to the rain-bearing northwesterly winds of the warmer sector of the cyclones, and less time to the icy southwesterly winds of the post-cold front sector. Validation of this model awaits a detailed analysis of sea level atmospheric pressure records for the South Indian Ocean sector of the Southern Ocean. Such an analysis for the Pacific region of the Southern Ocean showed that the direction of atmospheric pressure gradients governs whether warm north-easterly or cold southerly air flows over Macquarie Island and hence determines air temperature there (Adamson et al. 1988).

3.2 Topography

Marion Island is 290 km^2 in area and the highest peak is 1 230 m above sea level. Prince Edward is 45 km^2 in area and the highest peak is 672 m above sea level. Marion Island consists of a central highland area sloping down to a coastal plain which on the northern and eastern sides forms a 4 to 5 km wide area rising gently from sea level to the foot of the mountainous interior at about 300 m altitude (Figure 15.5). The western and southern coastal areas consist of a narrow discontinuous plain of less than 100 m altitude, having been eroded by wave action caused by the strong westerly winds. Much of the low-altitude area supports closed vegetation. The southeastern part of the Prince Edward Island slopes up gently from the coast to the top of a central plateau, a distance of about 7 km. The plateau is separated from the northwestern coastal lowlands by a precipitous escarpment.

3.3 Geology

The islands are located near the centre of the West Indian Ocean Ridge and are the surface expressions of a mantle plume marking the present position of a long-lived hotspot. They were considered to be extinct volcanoes but in September 1980 there was a small eruption on the west coast that resulted in a lava flow covering about 9 ha (Verwoerd et al. 1981) and some soil profiles contain buried A-horizons under volcanic ash deposits near the surface, attesting to sporadic volcanic activity in the recent past.

The lavas are typical oceanic island basalts. McDougall et al. (2001) recognised eight periods of volcanic activity, from 450 ka up to the Holocene one that started about 10 ka and extends up to the present. Two 'types' of lava flow can clearly be distinguished in the field (Verwoerd 1971, McDougall et al. 2001; Figure 15.6):

(1) Older grey lavas that have been glaciated (smooth striated outcrops, roches moutonées, moraines) and can be regarded as Pleistocene. They build much of the higher ground, as a radially arranged series of horsts, or wide ridges that are separated by depressions, or grabens, filled by younger flows. Glaciations have stripped the surface of the older lavas of all volcanic surface features. This horst and graben topography of alternating high and low segments has been ascribed to radial faulting (Verwoerd 1971). Although evidence of radial fracturing does exist, slope failure and land-sliding under the influence of gravity probably played a more important role in shaping the larger valleys (Chevallier 1986, McDougall et al. 2001).

(2) Younger black lavas that are all of Holocene age, because none of them show any glacial erosion effects and some

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Figure 15.6 Marion Island (below First Red Hill cinder cone): Three different geologies represented by young black lava (on the left), old grey lava (on the right) and cinder-cone scoria (in the foreground) converging and accommodating a small lava lake (tarn). The cushions on the scoria are *Azorella selago*.

encroach upon moraines. They comprise aa and (less commonly) pahoehoe flows and are associated with cinder cones (approximately 130 on Marion Island and 14 on Prince Edward). In addition, phreatomagmatic activity along coastal plains resulted in surtseyan tuff cones and hyaloclastite deposits (Verwoerd & Chevallier 1987).

3.4 Soils

Low temperatures and waterlogging result in low rates of chemical decomposition and clay mineral synthesis, but are optimal for accumulation of organic matter. The soils thus do not have well-differentiated profiles and those under vegetation at lower altitudes are highly organic. On the younger black lava flows the peat is shallow, generally less than 1 m deep but profiles up to 2 m have been found. On the older grey lava flows the peat can be deeper, 3 m being the deepest found (Schalke & Van Zinderen Bakker 1971).

Azorella selago cushions are the cardinal agent of soil formation on the island; decomposition of old leaves in the cushion interior results in an organic matrix mixed with volcanic ash. The cushions tend to grow toward the wind, the leeward margin dying off and exposing the organic/ash substrate which is then colonised by other plants (in fact, several vascular and bryophyte species establish directly on the cushions, rooting themselves in the decomposing matrix of the cushion interior). On flat areas the build-up of the organic matrix leads to impeded drainage and a higher water table, encouraging bryophytes which become the main agent of peat formation so that mire or bog vegetation develops. Typically, the water table in mire vegetation is near or at the surface and the peat is light brown and amorphous throughout the whole depth. Where drainage is better and the water table fluctuates, there is some horizon differentiation (Figure 15.7a); generally a light brown surface horizon up to 20 cm deep overlies a yellow-orange to light brown layer that extends to bedrock and which Smith (1978a) termed 'organic clay'. Indurated iron pans and/or organic pans sometimes occur in this clay layer, in which case gleying takes place and the clay is a yellow-grey colour beneath the induration.

Soils under slope plant communities possess better-developed profiles, especially where they are deep and where there is free drainage. Shallower soils (10–30 cm deep) consist of an organic horizon directly overlying mineral material which is generally scoria (volcanic ash). Deeper slope soils, especially those under fernbrake (Figure 15.7b), consist of a dark coloured A-horizon containing much litter and up to 30 cm deep. Below this a well-developed B-horizon of a 'yellow-brown loamy clay' (Smith 1976a) occurs, usually stained in the upper regions by the organic A-horizon. Red indurated plinthic layers sometimes occur in this B-horizon. In poorly drained soils on less steep slopes a gleyed horizon occurs beneath the plinthic layer and extends to bedrock.

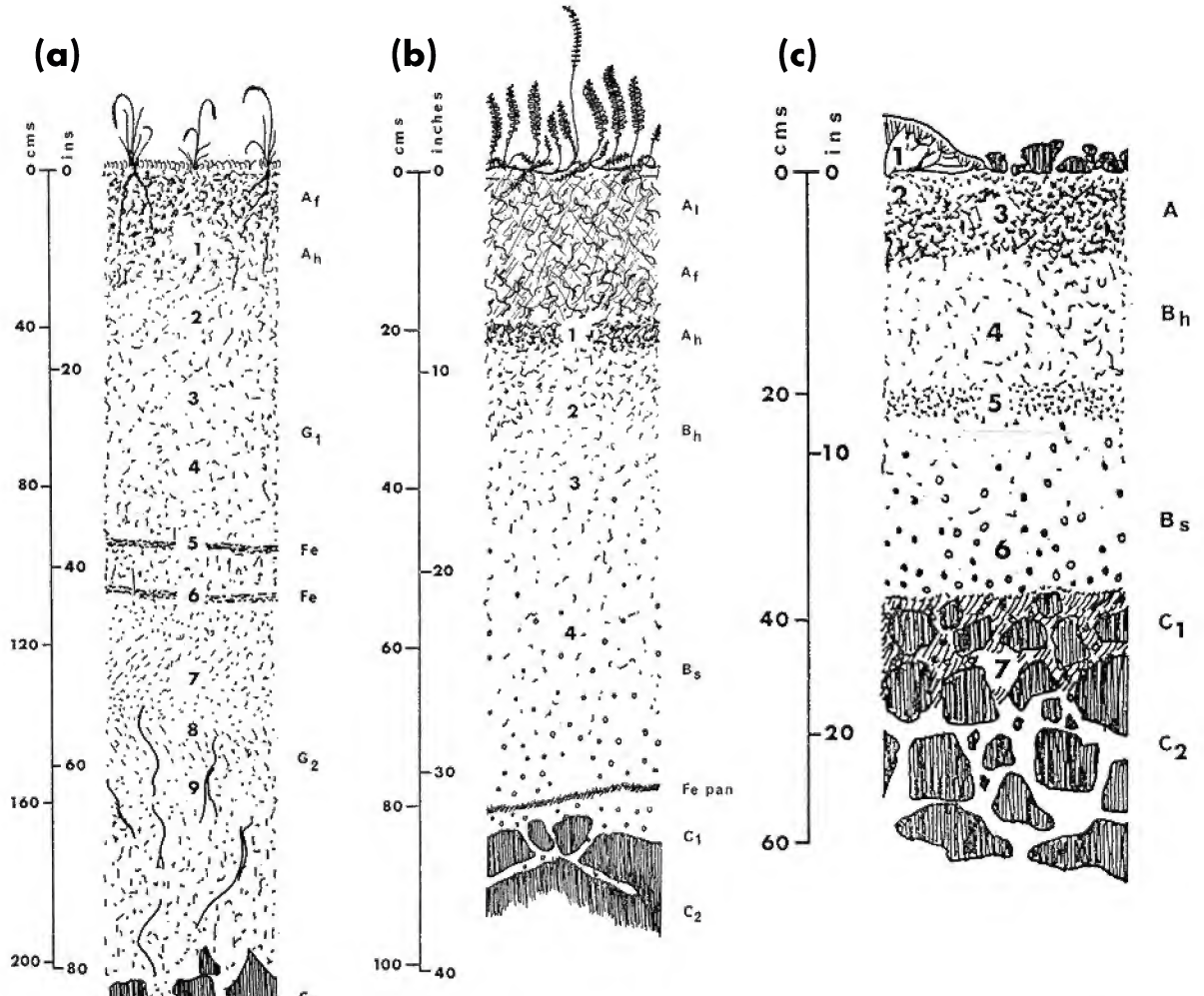

Figure 15.7 Profiles of soil under (a) mire, (b) fernbrake slope and (c) fellfield vegetations. Subhorizons are indicated thus: l = litter, f = fermentation, h = humus-enriched, s = sesquioxide-enriched, Fe pan = iron pan, G = gley horizon (from Huntley 1971; courtesy of A.A. Balkema, Cape Town).

Fellfield soils (Figure 15.7c) consist of skeletal, shallow gravelly 'loams' (Smith 1976a, 1978a). An A-horizon occurs beneath *Azorella* cushions but, where no plants are growing, the soil surface is either bare or covered by a layer of small pebble-sized scoria. Beneath the surface is a brown gravelly loam that becomes orange-brown with depth and contains much scoria. Bedrock is mostly within 10–15 cm of the surface, but some fellfield soils are deeper.

The polar deserts of the islands do not have soils, merely coarse scoria where any trapped moisture undergoes frequent freeze-thaw cycles. Vegetation (mosses, also with *Azorella selago* at lower altitudes) occurs mainly where seepage allows some moisture accumulation or where rock surfaces are exposed to moisture-laden winds.

True ornithogenic soils (soils essentially devoid of organic matter other than guano which overlies, but does not mix with, weathered rock) as described from Antarctica (Syroechkovsky 1959, Ugolini 1972) do not occur on the islands. Even in penguin rookeries the high rainfall prevents the build-up of guano deposits. However, many soils in the coastal zone are heavily influenced by birds and their profiles often contain evidence that birds were present at the site during their development (squid beaks, feathers; Smith 1977a). Following Tatur (1989), these may also be considered as ornithogenic soils. Rates of peat accumulation, especially around penguin rookeries, are strongly stimulated (Lindeboom 1979) and the soils are much darker (dark brown to black, compared with the light brown peat in areas not influenced by birds; Smith 1978b).

Since the soils of the islands developed from weathering of volcanic ash under cool humid conditions, they are suspected of containing allophanes as the dominant clay mineral, and the horizons of lowland soil profiles have been described as clays, organic clays or loamy clays (Huntley 1971, Smith 1976a, 1978a). However, the few mineralogical analyses carried out so far have not revealed crystalline or amorphous clay minerals (Gribnitz et al. 1986). There is a large concentration of glass fragments in the volcanic ash component of the soils. In many cases hydrolysis of the glass has lead to a yellow, brown or orange palagonite (the precursor of allophane) and Gribnitz et al. (1986) consider that what have been described as clays, organic clays or loamy clays are actually palagonitised fine-grained volcanic ashes, the cold climate and young age of the soils having precluded the formation of clay minerals. According to Gribnitz et al. (1986) the soils of the islands are formed from Holocene ash falls as follows:

- Accumulation of vegetable matter and raw humus on the surface of ash by colonising plants.
- Percolating humic acids stain the immediately underlying ash and mobilise some iron by attacking the palagonitised glass fragments.
- Precipitation of the iron at lower levels as hydroxides, the depth at which this occurs depending on the depth to the water table.

Three features make it difficult to classify the island soils using international systems: their immaturity, the negligible influence of parent material on the profiles, and the marked effect of slight variations in topography and wind exposure on these profiles. Taylor (1955) and Huntley (1971) classified Macquarie and Marion Island soils, respectively, according to the most important factors influencing their development. They regard soils under slope plant communities as high-moor peat and those of mire and bog areas as low-moor peat or fen and bog peat. The red-brown loamy soils of slopes on Marion Island resemble those of well-drained slopes and level ground beneath dry grassland on South Georgia, which have been termed brown soils by Lewis Smith & Walton (1975) since they approximate arctic brown soils.

Conditions such as waterlogging, low temperatures and high acidity lead to substantial amounts of organic acids in the soils. This, with the intensive leaching effect of the high rainfall, will favour podsolisation (Jenny 1941, Kononova 1966) and following most climatic systems of soil classification, the island soils should be predominantly podsolised. However, bleached eluvial horizons are not found in any lowland soil profiles, although Huntley (1971) and Smith (1976a) presented chemical data indicating the presence of an eluviated horizon below, and stained by, the A-horizon in some slope soils. Frequent or permanent waterlogging at or below the soil surface favours gleying and many of the lowland soils are gley (all horizons gleyed or semi-gley) or gleyed (only the lower horizons are so affected). In this respect they are similar to moorland soils of the southwestern Chilean islands which were classified by Papadakis (1969) as gley podsols (eluvial horizons masked by high organic matter content), humic gley soils and peaty soils. Tentatively, slope complex soils on Marion Island may be regarded as gley podsols and those of the mire complex as humic gley soils or, where the organic horizon lies directly on rock, as peat.

Soils under fellfield vegetation on Marion Island are approximately similar to fellfield soils of the northern hemisphere. Noting this similarity, Huntley (1971) referred to the island fellfield soils as rawmark. Taylor (1955) used the terms tundra soils and dry tundra soils when referring to fellfield soils on Macquarie Island. However, although subantarctic fellfield is the vegetation type that most closely resembles tundra vegetation, the well-drained soils under subantarctic island fellfield are actually very different from fellfield soils of northern hemisphere tundra, which are mostly poorly drained, strongly gleyed, mineral soils that overly permafrost.

3.5 Palaeohistory

All studies of geochronology to date have been carried out on Marion Island. Little is known of Prince Edward Island. The oldest K-Ar dates available for the lavas indicate an age of 450 000 ±10 000 years (McDougall et al. 2001). Since the island is only 2° of latitude north of the Antarctic Convergence, past falls in world temperature would have had the effect of shifting the Convergence closer to, and even northwards of, the island (Van Zinderen Bakker 1971). The glaciated surfaces of the old grey lavas and intercalated sediments with glacial characteristics testify to earlier glaciations. Hall (1978, 1981) described three distinct tills of different ages and concluded that during the last 300 000 years the island was subjected to three glacial episodes, each comprising a series of stades and interstades. At many localities the tills are separated by thick sequences of intercalated basaltic lavas and pyroclasts, suggested to have erupted during the interglacials as isostatic response to the removal of the weight of the ice (Hall 1981, 1982). However, although the two most recent periods of effusivity are clearly interglacial, some of the earlier ones seem to have coincided with glacial stages (McDougall et al. 2001).

A temperature drop of at least 3.5°C during the glaciations is indicated from the periglacial evidence (Hall 1978); this supports previous conclusions derived from palynological (Van Zinderen Bakker 1973) and ocean-floor sediment studies (Hays et al. 1976). During the interglacials the temperatures were as high as they are at present (Van Zinderen Bakker 1971). At some localities palaeosols are thought to have formed in the interglacial deposits (Hall 1978). Scott & Hall (1983) found that

organic-rich basal sediments associated with the interglacial deposits contain pollen spectra indicating a vegetation assemblage similar to that found today. Zonation in the pollen profile suggests that during the interglacial phase the ocean shore was close to its present position and that it moved some distance away at the onset of the glacial stage.

Other workers (Kent & Gribnitz 1983, Gribnitz et al. 1986) consider that Hall's palaeosols and tills are tuffs and tuff breccias, i.e. both are volcanogenic rather than glacigenic. They contend that the interpreted stratigraphic successions and the palaeoclimatological deductions of Hall (1978, 1981) are not substantiated. However, morainic deposits occur at many sites on Marion Island and it is not doubted that the island was glaciated in the Quaternary. The ice cover of the last glacial began to disappear rapidly about 12 000 years ago (Van Zinderen Bakker 1973) and the youngest lavas that have been dated (15 000 ±8 000 years BP; McDougall 1971) may have erupted in response to this disappearance. Radiocarbon dating of some mire peats on the island indicates minimum ages of 3 180 ±120 to 4 020 ±65 years BP (Schalke & Van Zinderen Bakker 1971). However, it is certain that many of the lava flows and overlying peat deposits are much younger (Scott 1985, Gribnitz et al. 1986).

4. Flora and Major Vegetation Patterns

The vascular flora of Marion Island consists of 22 native species, 18 introduced species and three species` of unknown status (N.J.M. Gremmen, pers. comm.). Of the alien plant taxa, 12 are still present on the island, but the other six have disappeared. Prince Edward has 21 native and three alien vascular species. A large proportion of the indigenous species has a wide ecological amplitude, and occurs over much of the range of habitats on the islands. There is a much higher diversity of cryptogams; for both islands ca. 100 moss, 42 liverwort and 100 lichen species have been recorded. Mosses and liverworts dominate many of the plant communities. Comprehensive descriptions of the island plant communities have been provided by Huntley (1971) and Gremmen (1981).

Because of the lack of trees and tall shrubs, the island presents a bleak or barren appearance when viewed from offshore. Closer inspection, however, reveals that the vegetation is not so sparse, or even as uniform, as it appears. Huntley (1971) recognised 13 plant communities (he termed them 'noda') based on floristic composition and autecological characteristics of the species. These were grouped into five complexes according to the most important factor controlling their distribution, such as salt spray, manuring, trampling, exposure and drainage. Gremmen's seminal work resulted in a phytosociological classification of the islands' vegetation that includes 41 plant communities. Environmental information (soil depth, moisture content, pH, loss-on-ignition, depth of groundwater, severity of manuring and trampling by animals and of salt spray) was related to floristic composition of the plant communities in order to group them into six community complexes. Subsequently, Smith & Steenkamp (2001) added one more complex.

The complexes are:

- The salt-spray (*Crassula moschata*) complex, restricted to shore-zone areas strongly affected by wind-blown sea spray. On the west coast the belt of salt-spray vegetation extends up to 300 m inland but on the east coast it is restricted to a narrower zone along the tops of coastal cliffs.
- The biotic (*Callitriche antarctica–Poa cookii*) complex, influenced by trampling and manuring by animals. This complex consists of a wide variety of communities, most of which occur on the coastal zone near colonies of seals and penguins. Inland, the influence of surface-nesters and burrowing species is also manifested by the presence of communities belonging to this complex.
- The *Blechnum penna-marina* complex (fernbrake communities) that dominates the vegetation of well-drained lowland slopes.
- The *Acaena magellanica–Brachythecium* complex, which forms at mire and lowland slope sites where there is pronounced lateral subsurface water movement. Communities of springs, flushes and drainage lines belong to this complex.
- The *Juncus scheuchzerioides–Blepharidophyllum densifolium* mire complex, dominated by bryophytes and graminoids and occurring on wet peat.
- The fellfield (*Andreaea–Racomitrium crispulum*) complex which forms in rocky habitats strongly exposed to wind. This complex, consisting of communities of the cushion-forming *Azorella selago*, bryophytes and lichens, dominates the vegetation above 300 m altitude. Fellfield communities also occur at lower altitudes where they exhibit fairly high (up to 60%) aerial vegetation covers.
- Polar desert. An important vegetation type (it covers about 120 km^2 of the 290 km^2 total area of Marion Island, but a much smaller proportion on Prince Edward Island) that was not included in the phytosociological study of Gremmen (1981) and for which there is no published ecological information. It was recognised as a cardinal habitat type on Marion Island by Smith & Steenkamp (2001; see also Smith et al. 2001) who placed it in a polar desert complex. It is the only vegetation type above 550 m altitude on the islands.

Soil moisture and exposure to wind are the most important factors determining variation between plant communities. The wet-sheltered dry, exposed gradient is also associated with a change from organic peat at sheltered sites to mineral soils at exposed sites. The type of plant community which develops at any particular point on the wet-dry gradient is mainly determined by manuring and trampling by seabirds and seals and/or by wind-blown salt spray.

Huntley's (1971) ecological classification and Gremmen's (1981) phytosociological classification implicitly define the terrestrial habitat types that occur on the island according to the main patterns of abiotic and biotic variation in the ecosystem, since both consider the role of the main environmental and biological forcing variables (moisture, exposure, parent soil material, salt spray and manuring and trampling by seals and seabirds) on the island. Canonical correspondence analysis and cluster analysis of soil chemistry and botanical variables for 176 sites on the island recognised 23 habitats in seven habitat complexes in a 'habitat classification' (Smith & Steenkamp 2001) that supports all of Huntley's and Gremmen's conclusions and that closely reflects the between-habitat variation in the relative magnitudes of the main abiotic and biotic forcing variables.

The habitat classification gives a broader grouping (21 habitats) than the phytosociological one (41 communities, plus variants of some communities). However, because it was based on plant types and soil chemistry considerations, rather than just plant species, the habitat groupings can be considered as nodal assemblages of plant communities having vegetation and edaphic affinities. They can thus be considered analogous to the six community complexes of the phytosociological classification since those complexes were recognised on the basis of

ecological and edaphic factors as well as floristic considerations. In this respect, the habitat classification gives a more detailed grouping of sites than the phytosociological scheme. It is also more detailed than Huntley's five nodal ecological complexes. Biotically influenced sites, in particular, are floristically (and edaphically) the most diverse on the island and these are distinguished as seven habitats in three separate complexes, rather than in one complex as in previous schemes. In contrast, the various types of drainage lines (also a floristically and edaphically diverse group) on the island are less finely categorised within the habitat framework than they are by the phytosociological classification. In some respects, the habitat analysis yields a similar dispensation of the drainage lines as does the ecological complex scheme of Huntley (1971) where they are included as two noda, together with mires and bogs, as part of the swamp complex. The main reason for establishing the habitat classification was to provide a framework of structurally and functionally well-defined units against which to detect and evaluate the effects of climate change and human-induced perturbations. Smith et al. (2001) describe the altitudinal distributions of the habitats and provide a scenario of how climate change is expected to affect them.

5. Vegetation Dynamics

5.1 Vegetation Succession

The very small number and wide ecological amplitude of the vascular plant species prevent the development of well-defined, floristically distinctive seral communities. However, a simplistic scheme of vegetation succession is as follows:

Rocky plateaus are colonised by lichens and cushion-forming mosses and dicotyledons (mainly *Azorella selago*). These initiate peat formation and also act as traps for fine, wind-blown volcanic ash. The peaty material fills the crevices and porous structure of the lava and impedes drainage. If the rate of water acquisition by the area is greater than the rate of drainage, bryophyte-dominated bogs develop. Peat accumulation raises the bog surface above the water table and mire-grassland vegetation dominated by graminoids and bryophytes results. Further peat accumulation may make the surface even drier and fernbrake vegetation then develops. However, closed fernbrake on flat, level areas is rare. Dry mire communities dominated by *Blechnum penna-marina, Racomitrium lanuginosum* and *Uncinia compacta* generally represent the culmination of the wet-dry succession on level surfaces.

Where drainage from the fellfield area is unimpeded, the cushion plants develop a stable peat for fernbrake elements to develop. At first these elements may arise epiphytically on, or in the shelter of, the cushions, but eventually extend across the peat to form an open type of fernbrake that is often succeeded by a closed carpet of *Blechnum penna-marina*. This sequence from fellfield to fernbrake occurs predominantly on slopes. On flat plateaus, impeded drainage (caused by peat blocking the drainage channels) diverts the fellfield-fernbrake succession to the one toward mire or bog vegetation.

The pathway of primary succession on cinder cones follows a simple scenario; the lower slopes are less exposed to wind, more stable and climatically less extreme than the upper reaches of the cones and this allows the establishment of *Azorella selago*. Several vascular and cryptogam species grow as epiphytes on the cushions and organic matter built up under the cushions consolidates the scoria. This pattern of colonisation and succession proceeds up the slope (Figure 15.8), and the recent warming of the island is suspected to be increasing the rate at which this is occurring.

At coastal rocky sites subjected to salt spray, the fellfield is dominated by *Azorella selago* and *Crassula moschata*. Peat accumulation in these areas results in a well-developed salt-spray vegetation dominated by *C. moschata* and *Cotula plumosa*. Impeded drainage results in a bog salt-spray community in which *C. moschata* and a few liverwort species occur.

Strong lateral flow of water may modify the vegetation at any level of succession, leading to a group of plant communities characterised, on slopes and stream banks, by the abundance of *Acaena magellanica* in the herb layer and *Brachythecium subplicatum* or *B. rutabulum* in the bryophyte stratum. These communities are associated with drainage lines, water tracks, flushes and springs in slope areas. Drainage lines in mires are characterised by a dominance of *Breutelia integrifolia* and *Bryum laevigatum*.

Animal activities may have a marked influence at any stage of succession. Other than Salvin's Prions (*Pachyptila salvini*), animals seldom establish nests or otherwise exploit fellfield areas, preferring mires and well-vegetated slopes. In the salt-spray zone, sites influenced by animals support luxuriant *Cotula plumosa–Poa cookii* vegetation that is especially characteristic of areas surrounding seal and penguin colonies (Figure 15.9). At mire and bog sites the influence of animals causes the development of wet biotic communities in which coprophilous, trampling-resistant species become established (mainly *Callitriche*

L. Mucina

Figure 15.8 Progressing primary vegetation succession in upslope trend on the northern slopes of Junior's Kop. The green patches on the slope are cushions of *Azorella selago,* with white patches of dry culms of *Agrostis magellanica*.

antarctica and *Montia fontana*). Where fernbrake communities are colonised by burrowing birds, closed tussock grassland dominated by *Poa cookii* develops (Smith 1976b). However, the occurrence and extent of tussock grassland (especially the inland type, the *Leptodontio proliferi–Poetum cookii brachythecietosum rutabuli* of Gremmen 1981) has declined markedly since the early 1970s. For example, tussock grassland occupied 7.8 ha of a 1 040 hectare inland study site on the island's eastern coastal plain in 1971–1972 (Smith 1976a, 1977b). This shrank to 0.9 ha by 1991 (Smith et al. 2001). This observation was made on only ca. 8% of the lowland area supporting closed vegetation but the same trend has been observed over the whole island since 1975 (N.J.M. Gremmen, unpubl. observations of permanent quadrates). Mostly, the inland tussock grasslands have been replaced by closed fernbrake or dwarf-shrub fernbrake. The reason for the shrinkage of tussock grasslands is almost certainly related to the influence of feral domestic cats (*Felis catus*) on burrowing petrel and prion populations at the island during the same period. Cats were introduced to the island in 1949 and their population grew rapidly, by 23% per year; by the mid 1970s it was estimated at ca. 2 100 adults (Van Aarde 1979). Undoubtedly, the cats had a devastating effect on the petrel species of the islands; in the mid-1970s they were eating a minimum of 635 000 petrels and prions each year (Van Aarde 1980). Where petrels and prions burrow into slopes, their guano enriches the soils (Smith 1976b) and this results in a succession to tussock grassland. When the birds disappear, the tussock grassland reverts surprisingly quickly to one of the non-biotically influenced slope communities. In the case of the tussock grassland studied by Smith (1976b), there were 1.2 burrow entrances per square metre in 1972; by 1987 there were no burrows and the area was occupied by closed fernbrake (in the wetter areas by dwarf-shrub fernbrake). With the elimination of cats (the last was killed in 1991; Bester et al. 2000) there are indications that the petrel and prion populations are recovering (Cooper et al. 1995) and it remains to be seen whether this will reverse the shrinkage of the tussock grasslands. Tussock grassland is very common and widespread on Prince Edward Island, where cats were never present.

Another biotic factor that is increasingly affecting the vegetation of the islands, particularly the coastal zone, is the rising population of fur seals. Trampling by these animals has degraded extensive areas of tussock grassland. A similar situation occurred on Bird Island, South Georgia, where fur seals destroyed most of the tussock grassland (Bonner 1985).

5.2. Primary Production, Decomposition and Nutrient Cycling

The subantarctic climate is oceanic and in many respects cool-temperate rather than polar. Hence, the islands do not experience bitterly cold or dry periods and the vegetation growing season is long. Additionally, the plants are all C_3 photosynthetic types that are able to maintain fairly high rates of photosynthesis and growth under the consistently low temperatures. Annual primary production is consequently high, comparable to even the most productive temperate herbaceous plant communities (Smith, 1987a, b). The high annual production results in a substantial annual requirement for nutrients by the vegetation (Smith 1987c, 1988a). There is a paucity of grazers and predators (there are no indigenous herbivorous mammals and insects play only a small role in herbivory), so most of the energy and nutrients incorporated in primary production goes through a detritus chain, rather than a grazing chain. Decomposition, with the concomitant release of nutrients, is overwhelmingly the main bottleneck in nutrient cycling and primary production for most of the plant communities (Smith 1988b, Smith & Steenkamp 1992a). The consistently cool climate, high cloud cover and very high rainfall result in low soil temperatures and excessive soil moisture, both of which restrict microbial activity. That is the reason why peat accumulation (a major determinant of vegetation succession, Section 5.1) is such a conspicuous part of the ecosystems of the islands, at least at lower altitudes where plant growth is possible. Decomposition mediated by soil micro-organisms alone is simply too slow to satisfy the large annual requirement for nutrients by the vegetation. There are large concentrations of soil macro-invertebrates (earthworms, moth larvae, weevils, snails etc.) that, by feeding on plant litter, are responsible for the bulk of energy flow and nutrient cycling on the island (Crafford 1990a, Smith & Steenkamp 1992b). The activities of these animals are strongly temperature-dependent (Klok & Chown 1997, Chown et al. 1997) so, providing nothing else threatens their populations, increasing temperature will result in enhanced rates of litter consumption and hence of nutrient release, allowing the potential for increased primary production due to elevated temperature to be realised. Threats to the soil macro-invertebrates of the islands, and hence to ecosystem functioning, are discussed in Section 7.2.

6. Current Conservation Status of the Islands

The National Parks Act (Act 42 of 1962) does not list Marion or Prince Edward Islands in its schedule of National Parks; neither do the islands enjoy Provincial Nature Reserve status although juristically they are considered as part of the Western Cape. Statutory environmental protection for the islands (to the low water mark) is provided by the Environmental Conservation Act (Act 73 of 1989), in terms of which both islands were proclaimed as Special Nature Reserves on 3 November 1995. The Maritime Zones Act (Act 15 of 1994), Article 54 of the Sea Fishery Act (Act 12 of 1988) and The Fishing Industry Development Act (Act 86 of 1978) afford some control over exploitation of the maritime zone around the islands. Additionally, the Seabirds and Seals Protection Act (Act 46 of 1973) controls the capture and killing of most species of seabirds and seals on the islands and South Africa is an original signatory of the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR), which, while not impinging on national sovereignty rights, focuses on conservation and management of marine living resources on and around the islands.

Proclamation of the islands as Special Nature Reserves required the formulation of a Management Plan for the islands, which was published in 1996 (Department of Environmental Affairs and Tourism 1996). The primary aim of the management plan is the conservation and sustained preservation of the islands' unique ecosystems for all people of South Africa and for the scientific community at large. The plan recognises that the Prince Edward Islands are an integral part of South Africa's national heritage and territorial integrity and that a rational and rigorous management of the islands is in keeping with an emerging international ethos and political order that recognises a strong environmental ethic.

A Prince Edward Islands Management Committee (PEIMC) was established to implement the management plan, which contains many provisions and regulations to ensure that activities on the islands take place with the minimum of environmental disturbance. The Management Committee advises the Department of Environmental Affairs & Tourism (DEAT) on planned and existing activities on the islands. A Conservation Officer and Team Leader are appointed to each relief team to the islands and

together they are tasked with the day to day 'management' of the islands in terms of the management plan.

Under the management plan four zones have been designated on the islands. Zone 1 is a service zone that includes the Marion Island meteorological station and a small area surrounding it. Zone 2 is a buffer zone around the station which extends in roughly triangular shape between Trypot Beach, Junior's Kop and Ships Cove. Areas around the field huts are also considered as Zone 2 areas because of limited human impact. The rest of Marion Island is a Zone 3 or wilderness area, with the exception of areas where there are Southern Giant Petrel colonies, Gentoo Penguin colonies, three Wandering Albatross study colonies, and Greyheaded Albatross colonies. These colonies are Zone 4 or protected zone areas. The whole of Prince Edward Island is Zone 4.

V.R. Smith

Figure 15.9 King Penguin (*Aptenodytes patagonica*) rookery on Marion Island, surrounded by tussock grassland (*Poa cookii*) vegetation. Light green plants are *Cotula plumosa*.

Entry to these zones is controlled by a permitting system. The permits are issued by DEAT on the advice of the Prince Edward Islands Management Committee. Generally, all visitors to the islands receive permits for Zones 1 and 2. Personnel involved in field research are permitted for Zone 3 and some for work in bird colonies that have Zone 4 status. Other team members may apply for permits to Zone 3 or may accompany research personnel doing field work on the permits of the research personnel involved. Visits to Prince Edward Island take place only with special permission and under strict conditions. These include intensive efforts to reduce the risk of alien introductions to the island.

Collection of any material from the islands, irrespective of the zone in which the collections are carried out, is also regulated by a permit system.

7. Threats to the Islands' Ecosystems

7.1 Implications of Climate Change

A changing climate has implications for the indigenous biota of the islands, especially the terrestrial species, which have all evolved under the cool, humid conditions typical of subantarctic islands. Smith & Steenkamp (1990) proposed some scenarios of the direct effects of warming (and drying) for the biota of Marion Island and there have been a few case studies on particular taxa. Most have concentrated on the ecophysiological responses of particular organisms, or groups of organisms, to abiotic factors such as moisture, light and temperature. For example, Smith & Gremmen (2001) showed that the light/temperature response of photosynthesis in the lichen *Turgidosculum complicatulum* on Marion Island is such that under the prevailing climatic regime the lichen would exhibit near maximal photosynthesis rates for 75% of the photoperiod over the year, if sufficiently hydrated. A model of the photosynthetic response predicts that changes in temperature and radiation by the amounts known to have occurred in the past few decades, and even more drastic changes (temperature up by a further 2°C, radiation up by 10%), would negligibly affect the annual amount of carbon acquired, again provided the thalli remain hydrated. Incorporating hydration/desiccation cycles into the model resulted in a very substantial lowering of annual net carbon exchange. However, attempts to include the increase in aridity known to have occurred at the island since 1971 yielded conflicting scenarios for the effect on annual carbon acquisition, depending on whether atmospheric drying or thallus drying was considered.

Similar studies relating physiological performances to microclimate factors have been carried out on the insects of the islands. For each of the six weevil species of the islands, upper lethal temperature corresponds closely to the maximum microclimate temperature in the habitat of the particular species (Van der Merwe et al. 1997), suggesting that climatic warming might be deleterious to the weevils' survival. Klok & Chown (1997) examined the thermal tolerance and desiccation resistance of larvae of a flightless moth (*Pringleophaga marioni*, the most ubiquitous insect on the islands) and concluded that should the warming trend on the islands continue, it will have a profound negative effect on the moth population, especially if the warming is accompanied by increasing aridity.

It was suggested in Section 3.1 that the climatic change occurring in the subantarctic is associated with changes in sea level (atmospheric and oceanic) circulation patterns, changes that themselves have implications for the biota and ecosystems of the islands. For instance, approximately one million pairs of burrowing petrels and prions occur on Marion Island, and possibly even more on Prince Edward Island. By feeding in the sea and depositing guano on land they represent an important source of marine-derived nutrients and energy (Smith 1976b) and are therefore a major driving force in vegetation succession (Smith & Steenkamp 2001). The birds use atmospheric frontal systems to move between the islands and their feeding areas (Mendelsohn 1981), which may be several hundred kilometres distant, in the surrounding ocean. If atmospheric circulation patterns are changing, then the birds may not be able to reach their usual feeding grounds; alternatively, associated changes in oceanic circulation may move the feeding grounds to other localities. Hence, changing sea level circulation patterns may

be expected to influence the breeding success and population densities of these animals, with obvious implications for nutrient cycling and vegetation succession on the islands. Similar considerations probably apply to the large populations of seals, penguins and albatrosses.

Even the identity of Marion Island (with its sparse, low-growing vegetation devoid of trees, or even shrubs, and an avifauna consisting entirely of seabirds) is challenged by the changes in its climate over the past 30 years or so. In Section 2 it was shown that the most widely accepted definition of 'subantarctic' (at least its terrestrial connotation) is based on a hybrid scheme derived from a vegetation-based classification by Wace (1965) and a climatological classification by Holdgate (1964). The subantarctic region has no months warmer than 8.5°C (considered the lower temperature limit for tree growth) and occurs south of the southern limit of tree or shrub growth (distinguishing it from the cool-temperate zone to the north) and north of the southern limit of closed phanerogamic vegetation (delimiting it from the maritime or low Antarctic to the south). Prior to 1990 Marion Island fitted comfortably into the subantarctic category but in the 1990s mean temperatures for January, February and March were between 8 and 8.5°C. Only slight further warming will put the island into the south cool-temperate zone, a region where the oceanic islands are inhabited by tall shrubs, trees and land birds (even parakeets!).

7.2 *Alien Flora, Alien Animals and Human Influence*

Probably of greater importance than the direct effects of climate change on the biota of the islands, is that a warmer climate will increase the ease with which the island can be invaded by alien species (Bergstrom & Chown 1999). Such invasions, especially by functional groups generally not found on subantarctic islands (e.g. vertebrate and invertebrate predators, mammalian herbivores, particular groups of pathogens), represent by far the greatest threat to the indigenous biota of subantarctic islands. An example of this is the deleterious effect that introduced organisms are having on the Kerguélen cabbage (*Pringlea antiscorbutica*), the only species in its genus, endemic to four subantarctic island groups. The species is the last remaining relict of a once extensive circum-antarctic flora. The distribution of *P. antiscorbutica* on Îles Kerguélen and the Îles Crozet has decreased in the last 25 years due to grazing by introduced rabbits *Oryctolagus cuniculus* (Chapuis 1995). On Marion Island its distribution and abundance has declined alarmingly over the past 25 years for several reasons, all to do with invasive alien biota. The European Slug (*Deroceras caruanae*) was introduced to the island in the mid-1960s (Smith 1992) and the Kerguélen cabbage is one of its preferred food items there. The Diamondback Cabbage Moth (*Plutella xylostella*), a major pest of crucifers worldwide, is also a recent arrival on the island (first discovered in 1986; Crafford & Chown 1990) and *P. antiscorbutica* is its only host plant there. Many stands of the cabbage are severely infected by the moth. *Botryotinia fuckeliana* (conidial state: *Botrytis cinerea*), the causal organism of grey mould rot in crucifers and other vegetable crops, has also reached the island only quite recently (probably through vegetables sent as food for the island personnel; Kloppers & Smith 1998). Many stands of the cabbage have been infected by the fungus, whole plants collapsing into a black slimy residue.

The introduced house mouse (*Mus musculus*) on Marion Island offers a particularly striking example of how profoundly an invasive alien organism can influence the biota and ecosystem of a subantarctic island. House mice on the island feed mainly on soil macro-invertebrates such as moths and weevils (larvae and adults), flies, spiders, earthworms and snails. The mouse population is strongly temperature-limited and is increasing, probably as a result of ameliorating temperatures. Several studies have unequivocally established that house mice are cardinal determinants of the population dynamics of terrestrial macro-invertebrates on the island. Crafford & Scholtz (1987) showed that there are striking differences between Marion Island and Prince Edward Island (which is only 22 km away) in the size, structure and composition of their macro-invertebrate populations (and also in the maximum body size attained by the various species) and ascribed this to the fact that mice do not occur on Prince Edward. The severity of the impact that mice have on their invertebrate prey on Marion Island is illustrated by the fact that mice daily consume between 30 and 107 g of moth (*P. marioni*) larvae per hectare (depending on habitat; Smith et al. 2002), or an average consumption for the island's eastern coastal plain of 65 g per day (Crafford 1990b). This is equivalent to 0.7% of the annual mean biomass of larvae, which take a long time to mature (2 to 10 years; Crafford 1990a, b). Such a high daily consumption rate must have severe implications for an insect with such a long life cycle, especially since almost the whole of it comprises the non-reproductive phase. In the case of weevils, sympatric speciation associated with assortive mating owing to differences in body size is occurring in the *Ectemnorrhinus similis* species complex on the island (Chown 1990), and size-selective predation by mice might be considerably enhancing the rate at which this is taking place (Chown & Smith 1993).

Predation by mice on soil invertebrates directly influences other components of the biota of the island. For example, the Lesser Sheathbill (*Chionis minor*) is the only non-migratory bird species on the island and relies on soil macro-invertebrates as food in winter. Smith & Steenkamp (1990) proposed that escalating predation by mice on soil invertebrates could adversely affect the sheathbill population. Huyser et al. (2000) subsequently reported that between the mid-1970s and mid-1990s the island's sheathbill population decreased by 23%, whereas the one on Prince Edward Island did not change.

More insidious, but probably even more profound than these direct effects of house mice on the biota of the islands, is their influence on ecosystem functioning (primary productivity, decomposition and nutrient cycling). As was stated in Section 5.2, primary production on the island is high, which means that the vegetation has a large annual requirement for nutrients, most of which is met by litter-feeding macro-invertebrates. Increasing temperature is expected to increase productivity and nutrient demand even further. Since soil microbiological processes on the islands appear to be more strongly limited by waterlogging than by temperature (Smith et al. 1993), the increased temperature might not translate into substantially greater rates of nutrient release by soil microbes alone. However, the activities of detritivorous macro-invertebrates, which are responsible for the bulk of energy flow and nutrient cycling on the islands, are strongly temperature-dependent (Klok & Chown 1997, Chown et al. 1997) and increasing temperature will result in enhanced rates of litter consumption and hence of nutrient release, which will allow the potential for increased primary production due to elevated temperature to be realised. An increasing mouse population, through enhanced predation pressure on soil invertebrates, will decrease rates of nutrient cycling and cause imbalances between primary production and decomposition and hence affect, amongst other things, rates of peat accumulation. This, along with more direct effects of mice (e.g. granivory; Chown & Smith 1993) has important implications for vegetation succession and ecosystem structure and functioning on the island.

8. The Future

8.1 Future Research

Biological research on Marion and Prince Edward Islands is financially supported by the South African Antarctic Research Program (SANAP) of the Department of Environmental Affairs and Tourism (DEAT), which until 2003 also co-ordinated and defined the focus and objectives of the research. DEAT, with the Department of Public Works, maintain research laboratories at the meteorological station (Figure 15.10). Smith (1991) provided a synopsis of the directions and priorities of terrestrial biology research on the Prince Edward Islands during the 1970s and 1980s. Since 1990 the focus of the research has been very largely directed toward increasing the ability to rationally manage and conserve the biota and ecosystems of the islands, including predicting the effects of the very marked climate change that is occurring there. Special attention has been given to monitoring and conservation projects, in accordance with national (e.g. requirements for managing Special Nature Reserves) and international (e.g. CCAMLR) obligations. The directives identified by SANAP and against which terrestrial biology research projects carried out between 2000 and 2004 were being evaluated and are being supported by DEAT, were:

- Factors influencing spatial and temporal patterns in biodiversity.
- Indigenous and introduced species: differential responses to environmental change.
- Adaptation, plasticity and response.

In 2003 the research function of SANAP was transferred to the Department of Science and Technology (DST), and is co-ordinated by the National Research Foundation (NRF). Logistics and management of the islands remain the responsibility of DEAT. From 2007 research at the islands will be aligned with the themes of the International Council for Science's *International Polar Year 2007–2008* program (http://www.ipy.org/concept/index.html).

8.2 Development and Conservation Threats

The DEAT is committed to the conservation and preservation of the biota and ecosystems of the islands and in terms of the proclamation of the islands as Special Nature Reserves, the Management Plan must be adhered to in all future research and logistic activities. Two aspects have arisen quite recently that will test that commitment.

The Antarctic is increasingly fascinating tourists and antarctic and subantarctic tourism is growing faster than the average for tourism worldwide. Tourism visits to the Antarctic Peninsula islands, South Georgia and the Falkland Islands, the New Zealand subantarctic islands, Macquarie Island and the French subantarctic islands have increased exponentially over the past 25 years. The Prince Edward Islands have largely escaped this trend, mainly because in addition to being isolated they are not near other sites of tourist interest that can provide alternative possibilities for the tour operator to satisfy clients should the weather be bad during the time that the ship visits them. However, of late there has been an increasing interest in tourism to the islands. In November 2002 the South African supply vessel, the S.A. Agulhas, was chartered to take a large contingent of birdwatchers to both islands, although no one was allowed ashore. There is evidence that two unauthorised tourist landings occurred at Prince Edward in the late 1990s and since 1996 several tour operators have applied to DEAT for permission to visit the Prince Edward Islands and land on Marion Island.

Since the current Prince Edward Islands Management Plan does not explicitly address tourism, the PEIMC recommended to the Minister of Environmental Affairs and Tourism that permission for those visits be denied. However, the PEIMC recognised that pressure for tourism activities at the islands was likely to increase, that such visits would be far more preferable if undertaken under controlled, monitored circumstances, and also that tourism had a positive spin-off in terms of generating income for SANAP and increasing public awareness of the unique nature of the islands and the research and conservation efforts being carried out on them. Accordingly, the PEIMC recommended to the Director General of DEAT that an environmental impact assessment of tourism at Marion Island should be undertaken. A subcommittee of the PEIMC was tasked with the EIA, with the following terms of reference:

- Investigate the possibilities for controlled, limited tourism to Marion Island.
- Undertake an EIA of the impact of tourism at certain sites on the coast of Marion Island between Ships Cove and Trypot Beach.
- Investigate the possibility of construction facilities to house tourists in the event of an emergency, and of erecting structures such as catwalks that would mitigate the impact of people on the biota of the island.

The recommendations of the subcommittee (Heydenrych & Jackson 2000) were that large tours of more than 100 persons not be allowed under any circumstance, but that smaller groups of up to 100 persons may land on Marion Island under a permitting system under an Impact Management Plan to be drawn up by DEAT. Tour visits would be limited to Zones 1 and 2 on Marion Island and no tourism should be allowed on Prince Edward Island. The rest of the recommendations relate to the

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Figure 15.10 Meteorological Station and scientific base on the eastern lowland plain of Marion Island. Large cinder cone behind the station is Junior's Kop.

timing and number of tour ship visits, the size of landing groups, the infrastructure and manpower requirements needed before tourism activities would have an acceptable minimum impact on the ecosystem of the islands, the use of income from tourism to pay for that infrastructure to and monitor the effects of tour visits, and the need for tour operators to have comprehensive insurance against unforeseen circumstances that would negatively impact on the islands, such as oil spills that would require clean-up, search and rescue operations and emergency board and lodging. The subcommittee specifically recommended that no additional accommodation facilities be erected on the island to cater for tourists.

One recommendation of the subcommittee is especially of note—that tourism increases the risk of introducing new alien organisms to the island (see the analysis by Chown et al. 1998 showing very convincingly that increasing numbers of human occupants increase the risk of propagule transfer to an island). Most importantly, the recommendation specifically points out that new introductions might lead to severe impacts on the biota of an island, the costs of mitigation of which might be extremely high. An example is the possible introduction of rats to Marion Island. That would have an enormous impact and the expense of eradication would likewise be enormous, judging from the cost of successful eradications of rats from the much smaller and more accessible islands off New Zealand. An idea of the cost is given by the 1995 estimate made at a workshop on the possibility of eradicating house mice on Marion Island (Chown & Cooper 1995) that the poison bait alone would cost R2.75 million per year, and that the eradication programme would take several years. Added to that is the cost of spreading the bait by air (estimated at 2 000 hours helicopter flying time) and of putting measures in place to reduce the very real risk of poisoning scavenging birds—about two thirds of the skua population on Enderby Island, south of New Zealand, was killed through taking bait put out for rabbits (Torr 1993). Assuming that eradication of rats on Marion Island could be completed in three years, the 2003 estimate of total cost (manpower, bait, helicopter and ship costs) was ca. R37 million. The report of the tourism subcommittee pertinently, and very correctly, points out in its recommendations that such high mitigation costs cannot realistically be claimed from tour operators. The reality is also that South Africa does not have the resources to undertake such an exercise, which means that the introduced rats will become a part of the ecosystem of the island, an ecosystem that will be very different and much less valuable as a laboratory for furthering ecological knowledge and theory.

For this reason the possibility that tourism to the islands might become a non-option is to be welcomed. The Draft National Environmental Management Protected Areas Bill published in 2002 lists three main types of protected areas, Special Nature Reserves, Nature Reserves, and National Parks. Tourism is explicitly stated as one purpose for declaring a protected area as a Nature Reserve or a National Park, but the only stated purposes for establishing Special Nature Reserves are 'to protect highly sensitive, outstanding ecosystems, species, geological or physical features in the area and to make the area primarily available for scientific research or environmental monitoring'.

The second issue that will soon test DEAT's commitment toward the conservation and preservation of Marion Island, in particular, is that construction of a new base station on the island commenced in September 2003. This will take four years and will be followed by the dismantling and removal of the old station. Such activities will involve large numbers of personnel and the importation of a huge amount of material. DEAT and the Department of Public Works (which is carrying out the construction) have undertaken to put all possible measures in place to ensure that the activities do not result in new introductions of alien organisms and that they will be undertaken in a way that reduces environmental disturbance to a minimum. The acid test of the seriousness of their commitment will be the situation in five years' time. If at that time the island possesses a new ultramodern base erected over a wasteland of bare eroded peat and adjacent an urban dump (the site of the current base), and a whole suite of new alien organisms, then DEAT will have failed the test.

9. Definition of Biomes, Vegetation and Mapping Units

Spatial variation of the vegetation of the islands occurs on a very small scale, due to the influence of the hummocky topography formed by the lava flows on aspects such as insolation, shelter from wind, moisture deposition, retention and drainage, and peat accumulation. Except for fellfield and polar desert, large expanses of single vegetation types are quite rare; at low altitudes (<200 m) even very small areas generally contain several vegetation types. For instance, a vegetation map by Gremmen (1981, p. 72) shows 18 plant communities sharing an area of 0.5 ha on Marion Island. Eleven of these are mire communities, two are biotic, two are slopes and one is fellfield. Other than the mires, the rest of the communities occupy patches mostly smaller than 20 m^2. Mapping at the scale of the maps presented here would show the vegetation as mire. Smith (1976c, p. 17) provides a vegetation map for a 1.5 ha area 500 m north of the one in Gremmen (1981), on the same lava flow. There, the vegetation is mapped more coarsely, not according to phytosociological associations. There are four slope vegetation types, one mire type and one fellfield type. Most of the types are represented in more than one patch but the total areas occupied by each type are more or less equal. Together, the four slope types are more extensive than mire or fellfield, so at the scale of the maps here the vegetation would be indicated as slope vegetation. However, between the two sites the lava flow contains a similar-sized site dominated by fellfield and spatially the three sites (mire-dominated, slope-dominated and fellfield-dominated) cannot be depicted separately at the scale of the maps presented here. The particular lava flow extends about 2 km south, 1 km north, and about 4 km inland of the two sites. Overall, this pattern of either mire, slope or (less commonly) fellfield communities being locally dominant is repeated over and over across the lava flow, which is only one of many similar flows that comprise the low altitude region of the island. All that can be said is that the lavas are occupied by a mosaic of slope, mire and fellfield communities.

The situation is even more complex on the coast, since salt-spray plant communities and communities influenced by animals are added to the mosaic. It is only at higher altitudes that more uniform vegetation types (fellfield and polar desert) occur over expanses large enough to be able to delineate them at the resolution of the map. Even there, the transition between fellfield and the mire-slope fellfield mosaic is not a sharp one, nor is the transition from fellfield to polar desert. None of those units can be distinguished on the aerial photographs of Marion Island (there are no photographs for Prince Edward). To compile the maps presented here, the mapping units were delineated on basis of field research (vegetation samples, photographs taken from known locations and other field observations done during on-foot and helicopter-assisted expeditions).

Here we distinguish three groups of vegetation (and mapping) units:

- Marine Macroalgal Vegetation contains only one vegetation (mapping) unit: Subantarctic Kelp Beds. Due to a lack of appropriate field data we do not show this unit on the maps of the islands.
- Subantarctic Tundra. This group corresponds to the extent of Subantarctic Tundra Biome and is found on the islands' lower altitude (<300 m) regions. Vegetation units ST 3, 4, 5 and 6, form an intricate small-scale spatial mosaic. In terms of Gremmen's (1981) classification this mosaic encompasses, respectively, the *Juncus scheuchzerioides–Blepharidophyllum densifolium* complex (mire), the *Acaena magellanica–Brachythecium* complex (slope drainage lines, springs and stream banks), the *Blechnum penna-marina* complex (slope fernbrake communities), and low-altitude representatives of the *Andreaea–Racomitrium crispulum* complex (fellfield). It is not feasible currently to disentangle this mosaic in the form of discrete spatial units at conventional mapping scales. Therefore, in spatial terms (on our map), we summarise vegetation units ST 3, 4 and 5 into a single mapping unit called 'Subantarctic Mire-Slope Vegetation' with the hope of being able to depict them on a more detailed scale at a later stage. The same applies for vegetation units ST 1 and 2, which were mapped together as the mapping unit 'Subantarctic Coastal Vegetation Vegetation'.
- Subantarctic Polar Desert crowns the highest tops of the islands, and on Marion Island descends as low as 100 m in places. It might seem surprising, even paradoxical, to apply the term polar desert to a habitat on a mid-latitude island that receives such a high rainfall, and most vegetation ecologists have tended to avoid using it when describing vegetation formations on subantarctic islands. For instance, Huntley (1971) referred to the vegetation of the habitat as *Ditrichum–Bartramia* montane desert and included it with *Azorella selago* fellfield in a wind desert complex. On other subantarctic islands, vegetation formations corresponding to Marion Island polar desert have generally been considered as fellfield (Taylor 1955, Hughes 1987, Bergström 1998) or included with fellfield as a synusia in a Fellfield Formation (Lewis Smith 1993). However, fellfield (Fjaeldmark, Felsenfluren or Felsentundra) was originally applied to vegetation in which vascular plants, especially cushion-forming ones, are a conspicuous (even important) component of the vegetation. This is certainly not the case for the Marion Island polar desert habitat, which has strong similarities (a barren unstable surface caused by frost-sorting, supporting extremely sparse vegetation dominated by mosses or, more rarely, lichens) to high arctic polar deserts as defined by Aleksandrova (1970) and Bliss (1981). In fact, it is floristically even more polar desert-like than many of the high arctic sites those authors cite as examples, where vascular plants make up a much greater component of the vegetation than is the case for the polar desert habitat on the island. For example, in the polar desert uplands of Devon, Bathurst and Cornwallis islands (all > 75° N in the Canadian North Western Territory), four to six vascular plant species are typical, increasing to eight to 12 at snow flush sites (Bliss 1981). Ten vascular species occur at 900 m altitude on Ellesmere Island (Canadian N.W.T., 82° N), whereas none occur above 800 m on Marion Island. The vegetation of the polar desert habitat on Marion Island thus resembles the most extreme northern hemisphere polar deserts; those dominated by mosses and lichens have been termed 'polar barrens' (Benninghof 1974) or simply 'barrens' (Longton 1998), to distinguish them from fellfield where vascular plants are more important. One only has to examine the photographs in Ochyra & Bednarek-Ochyra (1999) and Figure 15.19 to be convinced of the congruency in equating the Marion Island habitat with polar barrens of theHigh Arctic.

The term 'wind desert' has also been used when referring to the high-altitude vegetation of the subantarctic islands (Taylor 1955, Wace 1965, Huntley 1971) but that is not necessarily a fitting descriptor of the vegetation or the main factors affecting it. This does not imply that wind is unimportant. The polar desert surface on Marion Island, like the polar deserts of the Antarctic and Arctic, is almost totally dominated by physical rather than biological processes, and frost-heaving, frost-sorting and freeze-thaw activity are strong and frequent (at high altitudes, freeze-thaw cycles occur every day of the year; Jan Boelhouwers, pers. comm.). The effect of wind is as much due to its contribution to substrate instability and drying as to its more direct effects on plant growth. In fact, within polar desert there is little correlation between plant cover and shelter from wind, except where the cause of the shelter also contributes to moisture deposition and/or retention.

10. Description of Vegetation Units

Marine Macroalgal Vegetation

AZm 2 Subantarctic Kelp Beds

Distribution On the coast and offshore on the leeward (eastern) side of Marion Island and Prince Edward Island.

Vegetation & Seascape Features Kelp beds are an important and spectacular element of the seascapes of the Prince Edward Islands. They form two well-separated vegetation belts. *Durvillea antarctica* forms a fringing macrophyte belt on the

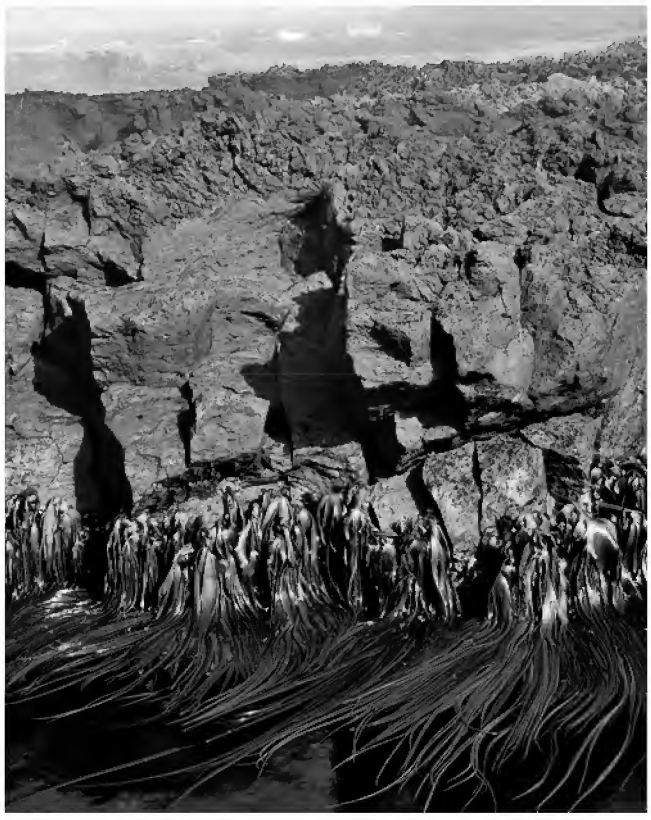

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Figure 15.11 AZm 2 Subantractic Kelp Beds: *Durvillea antarctica* in supra-littoral zone on coastal cliffs formed by head of young lava stream (near the Meteorological Station on Marion Island).

coastal rocks and cliffs. Holdfasts are attached to the rock in the lower littoral zone (De Villiers 1976) and the fronds (up to 8 m long) float freely on the water surface. *Macrocystis laevis* is found further off-shore, forming an interrupted belt up to 150 m broad.

Hydrology & Substrate The coastal cliffs and the sea shelf are built of young Holocene basaltic lavas. The tidal range on Marion Island is 71 cm at springs and 21 cm at neaps. Swell heights on the east coast may reach up to 4 m and as they travel unimpeded in deep water, they extend their energy against the sea cliffs, especially on the west, to lesser extent on the south and north coasts. Both kelp species prefer eastern lee shores (more or less outside the direct influence of roaring west winds and associated wave exposure), but *D. antarctica* occurs all around the island, being seemingly adapted to the relentless and large wave action that produces surf up to 30 m high in places. *M. laevis* forms dense 'kelp forests' of individuals up to 20 m long in water 5 to 20 m deep. It has a uniform distribution of frond-length frequency, suggesting that only the oldest fronds are lost by wave action or senescence. Strong wave action in more shallow water limits the availability of suitable habitat, whereas in deeper water light limits the kelp's growth (De Villers 1976, Attwood et al. 1991). Sea temperature at the island is around 4°C to 5°C in winter and 6°C to 7°C in summer (Mélice et al. 2003). Salinity is 32 to 33 psu (Pakhomov et al. 2002).

Important Taxa (both Macroalgae) *Durvillea antarctica* (d), *Macrocystis laevis* (d).

Remark 1 Mean biomass of *Macrocystis laevis* was estimated at 0.67 kg C m^{-2} and net production at 7.7 g C m^{-2} d^{-1} and 11.5 g C m^{-2} d^{-1} during April and August, respectively (Attwood et al. 1991). Most of the production of *M. laevis* is expected to be exported to the open ocean pelagic system (Attwood et al. 1991).

Remark 2 *Macrocystis laevis* is endemic to the Prince Edward Islands. It was described by Hay (1986); previously it was known as *Macrocystis pyrifera* (De Villers 1976, Gremmen 1981), a species that occurs around many islands in the Subantarctic and cold temperate regions of the Southern Ocean.

Remark 3 This vegetation unit is a subantarctic analogon to the AZm 1 Cape Kelp Beds (see Chapter 14 Coastal Vegetation), dominated by *Ecklonia maxima* and occurring in cold waters influenced by Benguela Current.

References De Villiers (1976), Gremmen (1981), Hay (1986), Attwood et al. (1991), Pakhomov et al. (2002), Mélice et al. (2003).

Subantarctic Tundra Biome

ST 1 Subantarctic Coastal Vegetation

Salt Spray Complex (Huntley 1971). 4.1. *Crassula moschata* Complex (Gremmen 1981). Coastal Salt-spray Complex (Smith & Steenkamp 2001, Smith et al. 2001).

Distribution On the eastern coasts of the islands this vegetation is mostly restricted to within 50 m of the shore but on the northern, western and southwestern coasts it is found further inland, since the predominant wind direction on the islands is northwesterly and southwesterly; on Marion Island ca. 1.5% of the area below an altitude of 100 m, is occupied by salt-spray vegetation.

Vegetation & Landscape Features Herbfields dominated by *Crassula moschata* (sometimes also by *Cotula plumosa* and at very exposed localities, *Azorella selago* co-dominates in a type of coastal fellfield vegetation).

Geology, Soils & Hydrology Mostly on black lava flows, on fibrous, black or dark brown peat that is often saline, being subjected to salt spray and occasional inundation by waves.

Climate The combination of low altitude and coastal location makes the microclimate of vegetation of salt-spray habitats extremely oceanic, with small diurnal and seasonal variation.

Important Taxa Herbs: *Cotula plumosa* (d), *Crassula moschata* (d), *Azorella selago*, *Callitriche antarctica*, *Colobanthus kerguelensis*, *Montia fontana*, *Ranunculus biternatus*. Graminoids: *Agrostis magellanica*, *Poa cookii*. Mosses: *Bucklandiella crispula*, *Calyptichaete apiculata*, *Campylopus clavatus*, *Muelleriella crassifolia*, *Orthotheciella varia*. Liverworts: *Clasmatocolea vermicularis* (d), *Fossombronia australis*, *Plagiochila heterodonta*.

Remarks This vegetation is frequently also influenced by birds, in particular by Rockhopper Penguins (*Eudyptes chrysocome*) and Fur Seals (*Arctocephalus tropicalis*).

References Huntley (1971), Gremmen (1981), Smith & Steenkamp (2001), Smith et al. (2001).

ST 2 Subantarctic Biotic Herbfield and Grassland

Biotic Complex (Huntley 1971). 4.2. *Callitriche antarctica–Poa cookii* Complex (Gremmen 1981). 4. Biotic Grassland Complex & 5. Biotic Herbfield Complex (Smith & Steenkamp 2001, Smith et al. 2001).

Distribution Found almost exclusively in coastal areas influenced by trampling and manuring by seabirds and seals. Also inland on slopes supporting colonies of burrowing petrels and on level areas surrounding Wandering Albatross and Giant Petrel nests; on Marion Island ca. 7% of the area at an altitude below

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Figure 15.12 ST 1 Subantarctic Coastal Vegetation: Coastal salt-spray vegetation dominated by *Crassula moschata* (yellow-green plant cover in the left foreground) and *Cotula plumosa* (light green cover in the right foreground and midground) on Marion Island.

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Figure 15.13 ST 2 Subantarctic Biotic Herbfield and Grassland: Vegetation heavily influenced by penguin and seal manuring and trampling at Cave Bay, Prince Edward Island. Tussocks of *Poa cookii* occur on peat pedestals, separated by wallows of a highly organic, eutrophic mud covered with *Callitriche antarctica*. Cave Bay was the site of the annexation ceremony in 1948.

100 m, but less than 1% of that between 100 and 500 m altitude is occupied by biotically influenced vegetation. The largest patches of biotic vegetation are found around large penguin rookeries (Kildalkey Bay, Bullard Beach and King Penguin Bay).

Vegetation & Landscape Features Coastal platforms with numerous depressions supporting *Cotula plumosa*-dominated herbfields and *Callitriche antarctica*-dominated organic mud as well as steep slopes supporting *Poa cookii*-dominated tussock grasslands. Saline habitats influenced by seabirds and seals; overall, species diversity is low.

Geology & Soils The soils are mostly peat with high concentrations of organic and inorganic nitrogen and phosphorus and they may be saline; where trampling is severe the soil surface may be bare and where both trampling and manuring are severe (e.g. seal wallows and penguin rookeries) an anaerobic, almost liquid, organic mud occurs.

Climate The combination of low altitude and coastal location makes the microclimate of salt-spray vegetation extremely oceanic, with small diurnal and seasonal variation. Soils denuded of vegetation through trampling can reach high surface temperatures (up to 35°C) on sunny days.

Important Taxa (*Aliens) Herbs: *Callitriche antarctica* (d), *Cotula plumosa* (d), *Montia fontana* (d), *Sagina procumbens** (d), *Azorella selago*, *Ranunculus biternatus*. Graminoids: *Agrostis stolonifera** (d), *Poa annua** (d), *P. cookii* (d), *Agrostis magellanica*, *Juncus scheuchzerioides*. Mosses: *Brachythecium rutabulum* (d), *Leptodontium gemmascens*, *Schizymenium campylocarpum*. Liverworts: *Clasmatocolea vermicularis* (d), *Fossombronia australis*, *Lophocolea randii*, *Lophozia cylindriformis* var. *australis*, *Marchantia berteroana*.

Remark 1 Twenty-nine bird and three seal species use the islands to breed and moult. Most of the birds, and the Subantarctic Fur Seal, occur in large numbers and have a significant impact on the vegetation, through trampling and manuring. Tussock grasslands occur around King Penguin (*Aptenodytes patagonicus*) and Macaroni Penguin (*Eudyptes chrysolophus*) rookeries and Elephant Seal (*Mirounga leonina*) wallows and are often pedestalled, the tops of the 30–100 cm peat pedestals are occupied by *Poa cookii* and their bases by *Cotula plumosa* or *Callitriche antarctica*, sometimes also *Montia fontana* and *Poa annua*. Areas occupied by Rockhopper Penguins (*Eudyptes chrysocome*), Gentoo Penguins (*Pygoscelis papua*), Crozet Cormorants (*Phalacrocorax atriceps*) or Fur Seals (*Arctocephalus tropicalis* and *A. gazella*) are generally occupied by vegetation dominated by *C. plumosa* and *P. cookii*. Inland slopes where burrowing petrels (10 species) or prions (two species) occur are also dominated by *P. cookii*, generally with *Acaena magellanica* and *Brachythecium rutabulum* in the understorey. In mires, Wandering Albatross nests are generally surrounded by vegetation dominated by *P. cookii* and also often containing other nitrophilous plants (*Callitriche antarctica, Montia fontana, C. plumosa* and *P. annua*) that are not normal constituents of mire vegetation.

Remark 2 Biotic vegetation, because of the disturbance through trampling and probably also the nutrient-enriched soils, is readily invaded by alien plant species, especially *Agrostis stolonifera, Sagina procumbens, Poa annua* and *P. pratensis*.

Remark 3 Liverworts are infrequent components of vegetation influenced by seabirds or seals; the notable exceptions are *Marchantia berteroana* and *Clasmatocolea vermicularis*.

References Huntley (1971), Smith (1978c), Gremmen (1981), Smith & Steenkamp (2001), Smith et al. (2001).

ST 3 Subantarctic Mire

Swamp Complex p.p. (Huntley 1971). 4.4. *Juncus scheuchzerioides–Blepharidophyllum densifolium* Complex (Gremmen 1981). 6. Mire Complex (Smith & Steenkamp 2001, Smith et al. 2001).

Distribution Mire vegetation is found in most lowland areas, being most extensive below 200 m, but found up to 400 m altitude. On Marion Island approximately 30% of the area below 100 m and approximately 3% of that between 100 and 300 m is occupied by mire vegetation; the largest mires on Marion Island are found on the coastal plain between Repetto's Hill and Long Ridge, inland of East Cape, Macaroni Bay and on the western coastal plain between Kleinkoppie and Kampkoppie.

Vegetation & Landscape Features Flat or only slightly sloping localities are dominated by conspicuous graminoids *Agrostis magellanica, Juncus scheuchzerioides, Uncinia compacta* and an abundant bryophyte flora (about 60 species). In wetter areas the dominating liverworts and mosses include *Blepharidophyllum densifolium*, *Clasmotocolea humilis, Sanionia uncinata* and *Distichophyllum fasciculatum*, while in drier mires *Jamesoniella colorata* and *Racomitrium lanuginosum* are prevalent and *Blechnum penna-marina* also occurs. In mires where there is pronounced lateral flow of water *Bryum laevigatum* and *Breutelia integrifolia* (sometimes also *Brachythecium subplicatum*) dominate.

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Figure 15.14 ST 3 Subantarctic Mire: Mire dominated by *Agrostis magellanica* and *Breutelia integrifolia* formed in a basin inland of Hendrik Fisher Kop on Marion Island.

Geology, Soils & Hydrology Mire vegetation occurs on both the older grey and younger black lava flows and overlies highly organic, generally waterlogged, peat which may be up to 2.5 m deep; since most of the mires receive water from surrounding areas as well as directly from rainfall, they are not ombrotrophic in the strict sense. However, most lateral water movement occurs at the bottom of the profile and the high rainfall leads to downward leaching and acidic upper horizons; the vegetation is effectively out of contact with the lower horizons and not influenced by mineral soil or water that has been in contact with mineral soil of surrounding areas. The vegetation relies on nutrients in rainfall (and to a lesser extent on biological nitrogen fixation) and so the mires can be regarded as ombrotrophic. In their hydrology and vegetation physiognomy subantarctic mires closely resemble raised bogs and blanket bogs of the northern hemisphere.

Climate High moisture content of mire peat dampens the already small diurnal soil temperature fluctuations. Freezing of the top layer (1–2 cm deep) of peat or bryophyte mat is a regular occurrence in autumn, winter and spring, even at low altitudes.

Important Taxa (*Aliens, ^{S}Submerged or floating macrophytes in lakes and tarns) Graminoids: *Agrostis magellanica* (d), *Juncus scheuchzerioides* (d), *Uncinia compacta* (d), *Agrostis stolonifera*^{*S} (aquatic form). Herbs: *Ranunculus biternatus* (d), *Acaena magellanica*, *Azorella selago*, *Blechnum penna-marina*, *Limosella australis*^{S}, *Lycopodium magellanicum*, *Montia fontana*, *Potamogeton nodosus*^{S}, *Sagina apetala**. Mosses: *Breutelia integrifolia* (d), *Bryum laevigatum* (d), *Distichophyllum fasciculatum* (d), *Ptychomnion densifolium* (d), *Racomitrium lanuginosum* (d), *Sanionia uncinata* (d), *Campylopus clavatus*, *Catagonium nitens*, *Plagiothecium ovalifolium*. Liverworts: *Blepharophyllum densifolium* (d), *Jamesoniella colorata* (d), *Clasmatocolea humilis* (d), *Lepidozia laevifolia* (d), *Fossombronia australis*, *Cryptochila grandiflora*, *Jensenia pisicolor*, *Leptoscyphus expansus*, *Lophozia cylindriformis*, *Metzgeria decipiens*, *Plagiochila heterodonta*, *Riccardia multifida*, *R. pinguis*, *Symphyogyna marionensis*. Lichen: *Peltigera polydactyla.*

Biogeographically Important Taxa (endemics of Kerguélen Floristic Province) Herb: *Ranunculus moseleyi* (on Marion only, but not recorded since 1987). Mosses: *Campylopus austrostramineus, C. subnites.* Liverworts: *Andrewsianthus carinatus*, *A. lancistipus*, *A. marionensis*, *Diplophyllum marionense*, *Metzgeria grollei*, *M. marionensis.*

Remark 1 Many ponds, crater lakes and tarns occur on the islands. Most are small (< 400 m^2 in area) and, except for the crater lakes which are found in the craters of some cinder cones, all are less than 1 m deep. The bottom is generally volcanic ash mixed with organic matter. Benthic algal felts occur in some, especially the smaller ones which are protected from the scouring effects of wind-driven wave action. The most common plants are *Ranunculus biternatus*, *Agrostis magellanica, A. stolonifera*, and *Juncus scheuchzerioides*. Rarer, and found only on the bottom of ponds and tarns, are *Limosella australis* and *Ranunculus moseleyi*. Bryophytes are uncommon on the bottoms of ponds and tarns (*Drepanocladus aduncus* is sometimes found there) but very abundant around the edges, especially *Sanionia uncinata*. The wettest mires have standing water on the surface and are probably more correctly considered as pools. They are dominated by *Agrostis magellanica, Juncus scheuchzerioides, Ranunculus biternatus* and *Sanionia uncinata*. Small streams are common on the islands, especially Marion Island. *Agrostis stolonifera* (submerged form) is the only vascular plant, and *Schistidium falcatum* the main bryophyte, that establish in stream beds.

Remark 2 The mires occur on both islands as an intricate, small-scale mosaic with fernbrakes and low-altitude fellfield. Ecotones between mire and fernbrake, and between mire and fellfield, are a significant component of the slope-mire (and some fellfield) mosaic.

References Huntley (1971), Gremmen (1981), Smith & Steenkamp (2001), Smith et al. (2001).

ST 4 Subantarctic Drainage Line and Spring Vegetation

Swamp Complex p.p. (Huntley 1971). 4.3. *Acaena magellanica–Brachythecium* Complex (Gremmen 1981). 3. Slope Complex p.p., incl. 3.5. Slope Drainage Line and Streambank Habitat & 3.6. Spring and Flush Habitat (Smith & Steenkamp 2001, Smith et al. 2001).

Distribution This vegetation occurs on both islands up to 400 m altitude (rare above 300 m).

Vegetation & Landscape Features On slopes with impeded drainage, in sheltered depressions and drainage lines of slopes, also on the banks of streams—vegetation dominated by the suffrutex *Acaena magellanica* and mosses (mostly *Brachythecium rutabulum, B. subplicatum* and *Sanionia uncinata*).

Geology, Soil & Hydrology Common on younger black lava and also on the sides of horsts formed by older grey lava, e.g. southern slopes of Skua Ridge. Soils are wet peat, sometimes with substantial volcanic ash.

Climate The complete plant cover restricts diurnal soil temperature fluctuations and the soils have never been observed to freeze.

Important Taxa (*Aliens) Graminoids: *Agrostis stolonifera** (d), *Poa cookii* (d). Herbs: *Acaena magellanica* (d), *Blechnum penna-marina*, *Montia fontana*, *Pringlea antiscorbutica*,

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Figure 15.15 ST 4 Subantarctic Drainage Line and Spring Vegetation: Moss-rich (*Breutelia integrifolia, Bryum laevigatum*) spring mire with abundant *Agrostis magellanica* at the Van den Boogaard River below Tafelberg on Marion Island.

best developed and show the greatest horizon differentiation of all the soils of the islands, and show some evidence of podsolisation; a dark brown or black A-horizon made up mainly of plant litter overlies a yellow-brown or yellow-grey loamy clay that sometimes contains red plinthic layers. The lower horizons of the soils are often gleyed.

Climate The *Blechnum penna-marina* fronds (10–18 cm long) are tightly packed vertically to form a thick carpet that protects the soil from insolation and radiative heat loss at night. Diurnal temperature variation is very small and the soils have never been observed to freeze.

Important Taxa Graminoids: *Agrostis magellanica*, *Poa cookii*, *Uncinia compacta*. Herbs: *Blechnum penna-marina* (d), *Acaena magellanica*, *Azorella selago*, *Grammitis poeppigiana*. Mosses: *Brachythecium rutabulum*, *Campylopus introflexus*, *Distichophyllum fasciculatum*, *D. imbricatum*, *Isopterygiopsis pulchella*, *Leptodontium gemmascens*, *Plagiothecium ovalifolium*, *Racomitrium lanuginosum*, *Sanionia uncinata*. Liverworts: *Acrobolbus ochrophyllus*, *Blepharophyllum densiflorum*, *Clasmatocolea humilis*, *Fossombronia australis*, *Jamesoniella colorata*, *Jensenia pisicolor*, *Lepidozia laevifolia*, *Leptoscyphus expansus*, *Lophocolea randii*, *Lophozia cylindriformis*, *Metzgeria decipiens*, *Plagiochila heretodonta*.

Biogeographically Important Taxa (endemics of Kerguélen Floristic Province) Herbs: *Elaphoglossum randii*, *Polystichum marionense*. Liverwort: *Symphyogyna marionensis*.

References Huntley (1971), Gremmen (1981), Smith & Steenkamp (2001), Smith et al. (2001).

Ranunculus biternatus. Mosses: *Brachythecium rutabulum* (d), *B. subplicatum* (d), *Sanionia uncinata* (d), *Breutelia integrifolia*, *Leptodontium gemmascens*, *Orthotheciella varia*, *Philonotis polymorpha*. Liverwort: *Lophocolea randii*.

References Huntley (1971), Gremmen (1981), Smith & Steenkamp (2001), Smith et al. (2001).

ST 5 Subantarctic Fernbrake Vegetation

Slope Complex (Huntley 1971). 4.5. Blechnum penna-marina Complex (Gremmen 1981). 3. Slope Complex p.p. (incl. Habitats 3.1 to 3.4) (Smith & Steenkamp 2001, Smith et al. 2001).

Distribution Extremely common on both islands, occurs up to 300 m altitude but rare above 200 m. On Marion Island approximately 24% of the area below 100 m, and approximately 10% of that between 100 and 300 m, is occupied by fernbrake vegetation.

Vegetation & Landscape Features Almost all slope communities are dominated by the fern *Blechnum penna-marina*. Closed fernbrake, the climax slope community, consists of an almost pure carpet of the fern; an open fernbrake is found in more exposed or rocky localities, where the fern is co-dominant with *Azorella selago* and cushion-forming mosses; in wetter habitats on less steep slopes, graminoids (especially *Uncinia compacta, Poa cookii* and *Agrostis magellanica*) and bryophytes such as *Jamesoniella colorata* and *Racomitrium lanuginosum* occur, but the vegetation is still overwhelmingly dominated by *B. penna-marina*.

Geology & Soils Mainly on black lava flows, rare on grey lava. Soils are the

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Figure 15.16 ST 5 Subantarctic Fernbrake Vegetation: Lowland area on the eastern side of Marion Island showing the mosaic of fernbrake (dark green vegetation on slope) dominated by *Blechnum penna-marina* and mires (light green and brown flat areas in between the fernbrakes) dominated by graminoids *Agrostis magellanica, Juncus scheuchzerioides* and *Uncinia compacta* and liverworts such as *Jamesoniella colorata* and *Blepharidophyllum densifolium*.

ST 6 Subantarctic Fellfield

Wind Desert Complex p.p. (incl. *Azorella selago* fjaeldmark) (Huntley 1971). 4.6. *Andreaea–Racomitrium crispulum* Complex (Gremmen 1981). 2. Fellfield Complex (Smith & Steenkamp 2001, Smith et al. 2001).

Distribution On both islands, dominant between 200 and 550 m altitude, although fellfield does occur at lower altitudes at exposed areas. On Marion Island ca. 33% of the area below 100 m, 72% of that between 100 and 500 m, and 15% of that above 500 m, is occupied by fellfield. Fellfield occupies around 46% of the total surface area of the island.

Vegetation & Landscape Features Dominated by *Azorella selago*, and frequently also by cushion- and ball-forming mosses. Several species grow on the *A. selago* cushions. By far the most common is *Agrostis magellanica* which may be co-dominant with *A. selago* in low-altitude fellfield. Crustose lichens are common. Total vegetation cover is from 5% to 50%, often more at lower altitudes.

Geology & Soils Fellfield occurs on both black and grey lava flows but is more common on the latter. Soils are more mineral than soils of any of the other vegetation types of the islands. They are generally skeletal but some are quite deep and consist of a matrix of organic matter (derived from *A. selago*) and volcanic ash.

Climate Fellfield occurs on rocky ridges and slopes that are very exposed to wind—this, with the sparse vegetation cover, means that the surface soil is subjected to frequent freeze-thaw cycles. On clear days soil surface temperature can rise to 15°C above air temperature.

Important Taxa ([A]Only in fellfield at altitudes below 250 m): Herbs: *Azorella selago* (d), *Acaena magellanica*[A], *Blechnum penna-marina*, *Colobanthus kerguelensis*, *Grammitis poeppigiana*, *Hymenophyllum peltatum*, *Lycopodium saururus*[A]. Graminoid: *Agrostis magellanica* (d). Mosses: *Andreaea acuminata*[A] (d), *A. acutifolia* (d), *Ditrichum strictum* (d), *Bartramia patens*, *Bucklandiella crispula*, *Catagonium nitens*, *Guembelia kidderi*, *Hypnum cupressiforme*, *Kiaeria pumila*, *Philonotis scabrifolia*, *Racomitrium lanuginosum*. Liverworts: *Herzogobryum vermiculare*, *Jensenia pisicolor*, *Jungermannia coniflora*, *Lepidozia laevifolia*, *Metzgeria decipiens*, *Plagiochila heterodonta*.

Biogeographically Important Taxa (endemics of Kerguélen Floristic Province) Moss: *Valdonia microcarpa*. Herb: *Colobanthus kerguelensis*.

Remark 1 The terms 'Fjaeldmark' (Warming 1887), 'Felsenfluren' or 'Felsentundra' (Schimper & Von Faber 1935) were originally applied to polar vegetation that is sparse and in which vascular plants, especially cushion-forming ones, are a conspicuous (even important) component of the vegetation. Here, the English equivalent 'Fellfield' (Warming 1909) is used.

Remark 2 Overall, fellfield occupies a smaller proportion of the total area of the mire-slope-fellfield mosaic than do mire or slope communities but its importance increases with altitude up to the upper limit of the mosaic, which is between about 200 and 250 m altitude depending on aspect and exposure. On grey lava horsts that extend to, or almost to, the coasts (Long Ridge, Skua Ridge, Stoney Ridge, Kerguélen Rise) these are dominated by fellfield with patches of very wet mire vegetation. They are here mapped as fellfield.

References Huntley (1971), Gremmen (1981), Smith & Steenkamp (2001), Smith et al. (2001), Le Roux & McGeogh (2004), Le Roux et al. (2005).

ST 7 Subantarctic Cinder Cone Vegetation

Distribution On both Marion (approximately 130 cones) and Prince Edward Islands (14 cones).

Vegetation & Landscape Features Cinder cones are a prominent landscape feature. Most of them have no vegetation, but where the scoria is relatively stable, some sublithic mosses and hepatics (protected by the top layer of scoria fragments) may occur.

Geology Holocene cones of red volcanic ash (scoria) are a prominent feature on both islands, representing the centres of explosive eruption of the younger black lavas. The scoria consists of vesicular fragments from cm to dm in size, mostly loose but in some places welded into layers.

Climate The macroclimate of cinder cones is harsh due to wind exposure but the sublithic microclimate (high humidity and, on sunny days, warm temperatures) is favourable for bryophyte growth.

Important Taxa ([S]Sublithic) Mosses: *Catagonium nitens*[S], *Ditrichum conicum*, *D. strictum*, *Hypnum cupressiforme*[S]. Liverworts: *Acrobolbus ochrophyllus*[S], *Herzogobryum vermiculare*[S], *Lepidozia laevifolia*[S], *Metzgeria decipiens*[S], *Plagiochila heterodonta*[S]. Herbs: *Azorella selago* (d), *Colobanthus kerguelensis*, *Hymenophyllum peltatum*, *Pringlea antiscorbutica*.

Remarks Gremmen (1981) considers this cryptic vegetation found on some cinder cones as a part of the fellfield (the *Andreaeo acutifoliae–Racomitrietum crispuli hypnetosum cupressiformis*).

Reference Gremmen (1981).

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Figure 15.17 ST 6 Subantarctic Fellfield Vegetation: *Azorella selago* (large, green cushions) fellfield above Tafelberg on Marion Island, with *Ditrichum strictum* (small olive-green cushions) and the grass *Agrostis magellanica*. Peat and volcanic ash deposits are built up under the *Azorella* cushions.

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Figure 15.18 ST 7 Subantarctic Cinder Cone Vegetation: Sparse fellfield (with *Azorella selago* and *Agrostis magellanica*) and oligotrophic lake in the cinder-cone crater of Junior's Kop on Marion Island.

Polar Desert Biome

PD 1 Subantarctic Polar Desert

Wind Desert Complex p.p. (incl. *Ditrichum–Bartramia* montane desert) (Huntley 1971). 7. Polar Desert Complex (Smith & Steenkamp 2001, Smith et al. 2001).

Distribution On Marion Island polar desert occupies ca. 10% of the area below 300 m altitude, 32% of that between 100 and 500 m, and 98% of that above 500 m.

Vegetation & Landscape Features Mosses are the dominating plant group in this vegetation (*Andreaea acutifolia, A. regularis, Bartramia patens, Bucklandiella orthotrichacea, B. valdon-smithii, Dicranella gremmenii, Ditrichum strictum, D. subaustrale, Grimmia kidderi, Notoligotrichum australe, Philonotis scabrifolia* and *Valdonia microcarpa*). The moss cover is generally less than 2%; it may reach up to 50% or more in localities where snow-melt accumulates but such sites are very localised (seldom more than 2 or 3 m^2) and they are surrounded by large expanses (sometimes tens of hectares) of bare rock with only an occasional cushion-forming moss or crustose lichen. *Azorella selago* is the only vascular plant in the habitat but is infrequent, rarely attaining more than 2% cover and then only at altitudes below 650 m. It is absent above 800 m; lichens are mainly crustose forms and are much less common than in the fellfield habitats of lower altitudes (only a few have been identified).

Geology & Soils Polar desert is found mainly on the black lava flows since they are the dominant flows in the higher regions of the islands. There are no soils in polar desert; sometimes a thin, grit-like layer of volcanic ash occurs under and between the rocks, or the habitat may be found on large expanses of unconsolidated deposits of pebble-sized scoria with only the occasional rock or boulder on the surface; the scoria show various relict and active periglacial features and polar desert is dominated by physical, rather than biological, processes.

Climate Polar desert has the most extreme microclimate on the islands. The tops of the scoria layer are frozen almost every morning and the almost total absence of plants allows the same layer to reach high temperatures during periods of extreme sunshine. The free drainage and wind-drying (see notes below) make polar desert the driest habitat on the islands.

Important Taxa Mosses: *Ditrichum strictum* (d), *Andreaea acutifolia*, *A. regularis*, *Bartramia patens*, *Bucklandiella orthotrichacea*, *Guembellia kidderi*, *Hymenoloma antarcticum*, *Notoligotrichum australe*, *Philonotis scabrifolia*. Lichens: *Pannaria dichroa*, *P. hookeri*, *Placopsis bicolor*, *P.* cf. *cribellans*. Herb: *Azorella selago*.

Biogeographically Important Taxa (endemics of Kerguélen Floristic Province) Mosses: *Bucklandiella valdon-smithii*, *Dicranella gremmenii*, *Ditrichum subaustrale, Valdonia microcarpa*.

Remarks In terms of area, fellfield and polar desert are the dominant habitats on the two islands, perhaps less so in the case of Prince Edward due to its much lower topography. Truly, if any vegetation types can be said to be archetypical of Marion and Prince Edward Islands, it is the two—fellfield and polar desert—that most closely resemble northern hemisphere tundra vegetation, and not the luxuriant coastal plant communities which have so far enjoyed the lion's share of biological investigations at the islands.

References Huntley (1971), Gremmen (1981), Smith & Steenkamp (2001), Smith et al. (2001).

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Figure 15.19 PD 1 Subantarctic Polar Desert on the high plateau of Marion Island with mostly black scoria overlying permanent ice. Vegetation is extremely sparse, comprising a few cushion-forming moss species.

11. Credits

The introductory text to the chapter as well as most of the descriptions of the vegetation units were written by V.R. Smith, who also produced the first version of the vegetation map. L. Mucina contributed by shaping the concepts of some vegetation units to the lists of species and by describing vegetation units (ST 3, PD 1 and AZm 2) and by introducing some changes to the original map after a joint excursion with V.R. Smith to Marion Island in April–May 2004. Most of the photographs were supplied by V.R. Smith, some by L. Mucina.

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Ecosystem Status and Protection Levels of Vegetation Types

16

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L. Mucina

Figure 16.1 The pride of South African nature conservation is the extensive and well-functioning network of statutory and private reserves and parks. One of the largest parks in the country—the Greater Addo Elephant National Park in the Eastern Cape—supports the last (albeit thriving) Cape population of African elephant (*Loxodonta africana*).

1. Introduction

The southern African region has a long conservation history—some of the first protected areas in the world were established in South Africa in the late 1880s. However, these were proclaimed with a strong focus on protecting hunting grounds and with limited concern for conserving biodiversity (Pringle 1982). As in many parts of the world, marginal areas unsuitable for agriculture or other land uses were set aside for conservation. Areas were proclaimed as protected areas for maintaining populations of large mammal species, for securing forest in the light of future afforestation, and for maintaining water catchments. In some instances, such conservation efforts had some detrimental effects on the vegetation (e.g. 'veld-improvement' or provision of water sources for the protection of large game; Rebelo 1992). A more detailed history of conservation areas and conservation planning is described in Rebelo (1997).

The protected area network has gradually increased over the last century to reach 7.93 million ha (6.25% of the land area) in 2005 (Figure 16.2). Most of the expansion occurred in the 1920s and 1930s through the addition of the Kruger National Park and then Kalahari Gemsbok National Park (today part of the Kgalagadi Transfrontier Park), and in the last 25 years. However, because biodiversity conservation was not the main rationale in selecting protected areas, the result is a protected area network that is not representative of the region's biodiversity.

Several reports (here referred to as conservation assessments) have highlighted the bias in protection levels across the region. The first assessment of the adequacy of protected areas in preserving South African vegetation types was realised in the 1970s (Edwards 1974). This assessment called for the protection of 5% of each vegetation type in formal reserves. Over the last 15 years, conservation assessments have evolved from ad hoc decisions to scoring approaches and lately to systematic approaches considering the issues of biodiversity representation and persistence. Recently, conservation planners have become more mindful of the challenges of implementing planning outcomes, resulting in innovative planning approaches that are implementation-oriented from the outset (Driver et al. 2003).

The approach used most often in South Africa (including in this assessment) to identify priority areas for conservation is referred to as systematic conservation planning (see Margules & Pressey 2000 and Driver et al. 2003 for more details). Systematic conservation planning is based on three key principles:

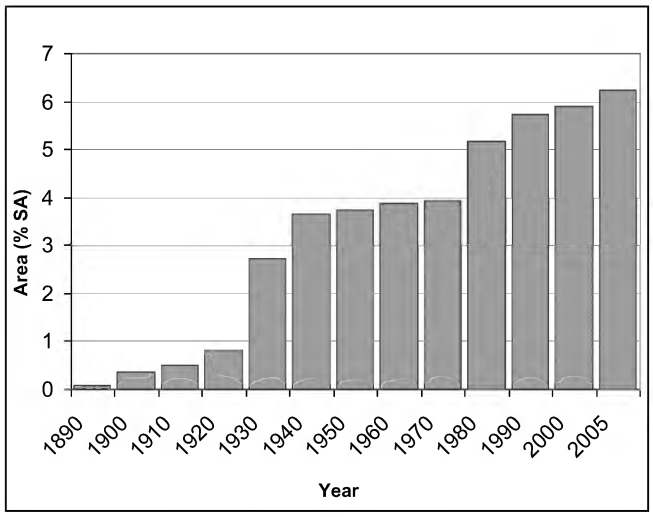

Figure 16.2 Expansion of protected area network (statutory and nonstatutory protected areas) in South Africa (SA) from 1890 to the present.

- The need to conserve a representative sample of biodiversity pattern, such as species and habitats (the principle of representation).
- The need to conserve the ecological and evolutionary processes that allow biodiversity to persist over time (the principle of persistence).
- The need to set quantitative biodiversity-based targets that tell us how much of each biodiversity feature should be conserved in order to maintain functioning landscapes. These targets should ideally be based on best available science, rather than on arbitrarily defined thresholds (such as 10% of all features).

In many parts of the world and especially in southern Africa, current conservation assessments include a wide array of features: various biodiversity features (biodiversity pattern, e.g. species and habitats and ecological and evolutionary processes), land use opportunities and constraints in order to lay the basis for successful implementation. For example, considerable attention is given to the use of conservation assessments in land use planning, extending biodiversity conservation beyond formally protected areas.

Through the series of conservation assessments (starting with Edwards 1974), several conservation priority areas have been identified such as the Cape lowlands, the central Grassland and the Succulent Karoo (Edwards 1974, Greyling & Huntley 1984, Jarman 1986, Rebelo 1997). However, the implementation of new protected areas or conservation measures has been limited to a certain extent (e.g. Jarman 1986, Rebelo 1994). Recently, major regional planning initiatives have been undertaken or are under way to implement conservation programmes, for example in the Cape Floristic Region (C.A.P.E.), the Succulent Karoo (SKEP), the Albany Thicket Biome (STEP), and in several South African provinces such as KwaZulu-Natal, Gauteng and Mpumalanga. Some of these have led to large multi-sectorial conservation programmes involving partnerships between government, civil society and the private sector.

As a signatory of the Convention on Biodiversity, South Africa is obliged to produce a National Biodiversity Strategy and Action Plan (NBSAP), which is currently being developed. The conservation assessment, which follows below, forms part of the spatial component of South Africa's first NBSAP. Systematic conservation planning methods used were based on comprehensive spatial information of biodiversity pattern and ecological processes, biodiversity targets, and current and future land use patterns. This provided an up-to-date assessment whose products are geared towards implementation, each accompanied by a set of guidelines and recommendations (see Driver et al. 2005).

Our assessment is in threefold. Firstly, we review the ecosystem status of the vegetation of South Africa, Lesotho and Swaziland, assessing the spatial pattern of current habitat transformation and relating this to biodiversity targets set for each vegetation type. Secondly, we review the adequacy of the current protected area network in representing all vegetation types. Conservation priorities are then identified on the basis of ecosystem status, protection levels and irreplaceability. The Prince Edward Islands were not subject to this analysis due to their status of Special Reserve (see chapter on Vegetation of subantarctic Marion and Prince Edward Islands).

The NBSAP biodiversity assessment used a relatively coarse-filter approach designed to identify areas that require a finer-scale assessment (if this has not already been done). Terrestrial conservation priority areas were identified on the basis of many biodiversity features including species (endemic and threatened

plants and animals), ecological and evolutionary processes (such as biota migration along the escarpment) and habitats (vegetation types) (Rouget et al. 2004). Here we focused on conservation priorities identified using vegetation types only, a reasonable surrogate for many biodiversity features in southern Africa (Lombard et al. 2003)[1].

2. Patterns of Current Habitat Transformation

Human activities can impact on areas of natural vegetation in various ways, from minor degradation to total conversion. Loss of natural habitat as a result of land uses such as agriculture, forestry, mining and urban development, remains the single most important threat to biodiversity (Wilcove et al. 1998). In southern Africa, and other developing regions, the natural vegetation is often partially degraded (albeit not completely cleared) by livestock grazing, soil erosion often following too frequent fires or by invasion by alien plants. Given the fact that approximately two thirds of southern Africa is used for extensive livestock farming, grazing is likely to have an important impact on the natural vegetation. However, mapping grazing impact over large areas is complex, especially in arid areas, and not enough spatial information is currently available to provide a proper assessment of grazing impacts on southern African vegetation types. This assessment focuses on irreversible loss of natural habitat as a result of croplands (including plantations), urban and rural settlements, mining and roads. The extent of alien plant invasions and habitat degradation was excluded due to lack of appropriate data at a national scale (see Box A). For this purpose, we used the National Land Cover (NLC), a comprehensive data source derived from 1996 satellite imagery (Fairbanks et al. 2000). We acknowledge that, due to the lack of spatial data on grazing impacts, as well as the fact that the NLC is not up to date, the impacts of human activities on the natural vegetation are far greater than is reflected here.

About 16% of the vegetation in South Africa, Lesotho and Swaziland has been irreversibly transformed (croplands: 14%, urban areas: 1.1%, roads: 0.5% and mines: 0.1%) (see Figure 16.3). Most habitat transformation has occurred in Gauteng, the Cape lowlands and the eastern seaboard, resulting in considerable differences in the spatial extent of habitat transformation between biomes and vegetation types. Fynbos and Grassland are the two biomes most severely impacted upon by human activities; almost 30% of their original extent is now covered by cropland, urban areas, mines or roads (Table 16.1). In contrast, only 5% of the Succulent Karoo and Nama-Karoo Biomes has been irreversibly transformed. Only two vegetation types have lost more than 90% of their original extent, and 11 more than 75% (Table 16.2). The large majority of vegetation types still comprise extensive areas of natural vegetation (although they could be heavily grazed or invaded by alien plants): 326 vegetation types (74.8%) still have 75% or more of their original extent intact.

Except for a few vegetation types, South Africa, Lesotho and Swaziland appear to have been marginally impacted by irreversible habitat transformation. However, habitat transformation is underestimated due to inaccuracies in mapping land uses and the lack of spatial information on habitat degradation. In many parts of southern Africa, it has been reported that habitat degradation due to alien plant invasion, overgrazing and harvesting of natural resources (wood, flowers, medicinal plants) had a far more extensive impact on vegetation than the transformation of natural habitat (Hoffman & Ashwell 2000; Box A). Degree of habitat fragmentation and alien plant invasion within vegetation types could not be taken into account (but see chapter on Vulnerability).

Pattern of habitat transformation among vegetation types can be used to crudely identify conservation priorities. Vegetation types that are already modified should ideally receive more conservation efforts than those relatively free of human activities because the former are currently more vulnerable to habitat fragmentation and degradation. For heavily transformed vegetation types, this could represent the last opportunity to conserve remaining fragments of natural vegetation and their associated species. However, other factors should be taken into consideration for identifying conservation priorities: biodiversity targets and protection levels (see below).

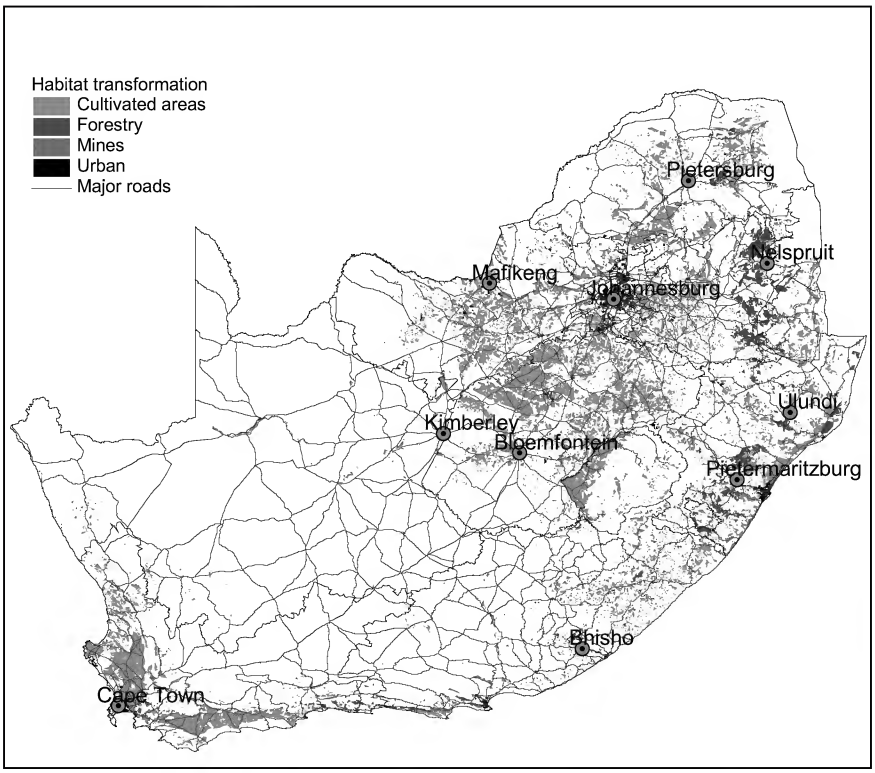

Figure 16.3 Extent of irreversible habitat transformation (cultivated areas, forestry plantations, mines, urban areas and roads) in South Africa, Lesotho and Swaziland. This map does not take habitat degradation, for example due to grazing or alien plant invasions, into account.

[1] The spatial components of the NBSAP also included freshwater, marine and estuarine conservation assessments using systematic conservation planning methods (for more on the spatial component of the NBSAP, please see Driver et al. 2005).

3. Setting Biodiversity Targets

Targets are an integral part of contemporary conservation planning, implementation and monitoring. Systematic conservation planning is dependent on explicitness, accountability and defensibility in identifying priority conservation areas (Margules & Pressey 2000). As a part of this, conservation targets underpin this process as they provide a clear purpose for conservation decisions, lending them accountability and defensibility (Pressey et al. 2003). Targets are basically quantitative interpretations of broad conservation goals that are established in policy, by experts, implementing agencies or other stakeholders (Margules & Pressey 2000, Pressey et al. 2003). For example, a conservation agency may specify that it wishes to conserve at least 10% of each vegetation type and three populations of each endangered species within its jurisdiction. Consequently, targets also provide a benchmark against which to measure the success of conservation action.

Table 16.1 Habitat transformation and protected status of biomes and azonal vegetation in South Africa, Lesotho and Swaziland. Only statutory reserves (national parks, provincial and local authority reserves) were considered.

Biome or azonal units	Area (km²)	% Total area	% Remaining	% Protected
Albany Thicket Biome	29 127.547	2.30	88.02	6.06
Azonal Vegetation	28 979.583	2.29	78.13	4.59
Desert Biome	7 166.443	0.57	99.16	14.56
Forests	4 731.407	0.37	94.08	16.73
Fynbos Biome	83 946.257	6.62	68.79	10.10
Grassland Biome	354 593.501	27.97	64.96	1.68
Indian Ocean Coastal Belt	14 282.489	1.13	50.71	1.54
Nama-Karoo Biome	248 278.626	19.59	97.65	0.61
Savanna Biome	412 544.091	32.54	77.06	8.75
Succulent Karoo Biome	83 283.976	6.57	94.64	2.93

Table 16.2 The ten vegetation types most impacted by irreversible habitat transformation (croplands, urban areas, mining and roads).

Vegetation type	Remaining (ha)	% Remaining	% Protected
Lourensford Alluvium Fynbos	491.1	8.88	4.2
Swartland Shale Renosterveld	47 369.9	9.58	0.5
Swartland Silcrete Renosterveld	1 015.9	10.17	0.6
Central Rûens Shale Renosterveld	27 004.0	13.42	0.4
Western Rûens Shale Renosterveld	16 545.4	13.90	0
Eastern Rûens Shale Renosterveld	53 161.2	19.20	0.4
Cape Flats Sand Fynbos	10 511.5	19.27	0.1
Elgin Shale Fynbos	5 817.5	20.82	5.9
Swartland Granite Renosterveld	20 259.2	21.38	0.6
Rûens Silcrete Renosterveld	4 644.6	22.14	0.1

Table 16.3 The range of conservation targets estimated for vegetation types and summarised per biome and azonal vegetation. Targets were estimated using the species-area relationship with the goal being the area required to represent 75% of species that occur within a vegetation type.

Biome or azonal units	Targets (%)		
	Average	Minimum	Maximum
Albany Thicket Biome	19.0	19	19
Nama-Karoo Biome	19.6	16	21
Indian Ocean Coastal Belt	25.0	25	25
Savanna Biome	19.9	16	25
Grassland Biome	24.9	23	28
Azonal Vegetation	24.7	16	34
Desert Biome	32.0	28	34
Succulent Karoo Biome	24.7	16	34
Fynbos Biome	28.0	23	36
Forests	62.3	30	100

So how can we set biologically meaningful quantitative conservation targets for Southern African vegetation types? While there are some studies dealing with a range of species (e.g. Travaini et al. 1997), minimum viable population (e.g. Burgman et al. 2001), meta population (e.g. Lindenmayer & Lacy 1995), genetic diversity (e.g. Ferguson et al. 1998), community (e.g. Prins et al. 1998), habitats (e.g. Turner et al. 1999) or ecosystem (e.g. Noss 1996) targets, there is generally a paucity of work dealing specifically with targets for vegetation types.

The widely used 10% target, recommended by IUCN, when applied to our vegetation types implies that all are equal in terms of their species diversity, abundance and distribution. Most would agree that this is certainly not the case. Desmet & Cowling (2004) discuss a more biologically relevant method for setting targets for vegetation types using the power form of the species-area relationship (SAR). The SAR describes in mathematical terms the basic observation that one observes more species as one samples a larger area. Using Equation 1 it is possible to predict the number of species observed if a given percentage of a vegetation type was sampled, provided that the z-value for the vegetation type was known:

Equation 1: $S = A^z$

Here S and A denote the proportion of species and area rather than absolute values. This equation can be reordered to address conservation targets to determine the proportion of area of a vegetation type required to represent a given percentage of species:

Equation 2: $A = z\sqrt{S}$ or $\log A = \log S/z$

Published z-values for biotas range between approximately 0.1 and 0.4 (Rosenzweig 1995). Although this range in the exponent is small, the nature of the power curve means that for a species target of 75% (i.e. we wish to represent 75% of species occurring in this vegeta-

tion type within a reserve network), the area target for the vegetation types ranges from 5% to 48%, respectively (Desmet & Cowling 2004).

SKEP and STEP projects all used vegetation survey data (phytosociological relevés) to estimate the z-values for Succulent Karoo vegetation types. The same method was used here to estimate z-values for all southern African vegetation types. The details of the method used to develop the conservation targets for South African vegetation types is discussed in more detail in Desmet & Cowling (2004) and Rouget et al. (2004).

Relevé data for South Africa were obtained from three geo-referenced phytosociological relevé databases, comprising over 17 000 relevés. There are more phytosociological datasets available for the region but these have either not been captured or geo-referenced.

For South African vegetation types, estimates of z-values range between 0.13 and 0.25. After considerable discussion it was decided that the goal for statutory reserves should be to represent at least 75% of species that occur in a vegetation type within at least one or more statutory reserves. Using Equation 2 this goal translates to conservation targets ranging between 11% and 30%, respectively (see Table 16.3). For forest vegetation types the targets were based on those set for the Forest Assessment Process (Berliner & Benn 2004) and not the species-area approach. Targets for forests range between 30% and 100%. As would be expected, areas of the country rich in endemic species or high levels of plant species diversity such as Fynbos, Succulent Karoo and some Grassland Biome vegetation types have higher representation targets (i.e. require more area to represent the same overall proportion of plant species). Some rare vegetation types such as forests also have high targets.

4. Ecosystem Status

The identification of conservation priorities, at a vegetation type level, should take into consideration at least the following factors: plant species diversity and turnover, habitat transformation and protection levels. Ecosystem status takes into account the first two, species diversity and turnover (through biodiversity targets), and habitat transformation. Ecosystem status aims at identifying threatened ecosystems (here vegetation types). It draws on the Red List classification scheme developed by the IUCN and borrows the familiar terminology applied to species, such as critically endangered (CR), endangered (EN), vulnerable (VU) and least threatened (LT). Focusing conservation efforts on threatened species is crucial for maintaining biodiversity. However, only conserving the natural habitats in which species occur will ensure species persistence. The identification of threatened ecosystems is aimed at addressing this. The recognition of threatened ecosystems by international organisations such as the IUCN and national governments could prove to be a very powerful conservation tool. It is envisaged that specific land use restrictions will be enforced in threatened ecosystems. In South Africa, the new Biodiversity Act (10 of 2004) provides for the Minister of Environmental Affairs and Tourism to list threatened ecosystems. Threatening processes in these ecosystems will be listed in terms of the National Environmental Management Act (107 of 1998) as activities that require environmental assessment.

Although the Biodiversity Act in South Africa allows for the listing of threatened ecosystems, it does not specify a standard approach for identifying them. The approach proposed here focuses on the retention of ecosystem functioning (such as pollination, nutrient cycling) and plant species diversity at the landscape scale. Vegetation types were classified based on the extent of remaining area (currently not transformed) of each

Box A: The extent of habitat degradation in South Africa

At least 8% of South Africa, Lesotho and Swaziland is invaded by alien plants (Versfeld et al. 1998). Over 700 alien plant species have become naturalised, 120 of which are considered as major invader plants, invading natural habitat (Nel et al. 2004). It is not clear whether some vegetation communities are more resilient to plant invasions than other, but some vegetation types have been heavily invaded. This applies to fynbos vegetation, thicket and highveld grassland (Rouget et al. 2002).

Loss of plant cover, change in species composition and bush encroachment are the major forms of habitat degradation in South Africa (Hoffman & Ashwell 2000). Loss of plant cover is the most important degradation problem in grasslands in the higher-rainfall eastern part of the country. Change in species composition occurs mostly in the dry west. Habitat degradation due to removal of woody species is widespread in shrubland and savanna woodland of the Limpopo Province (see Figure A1).

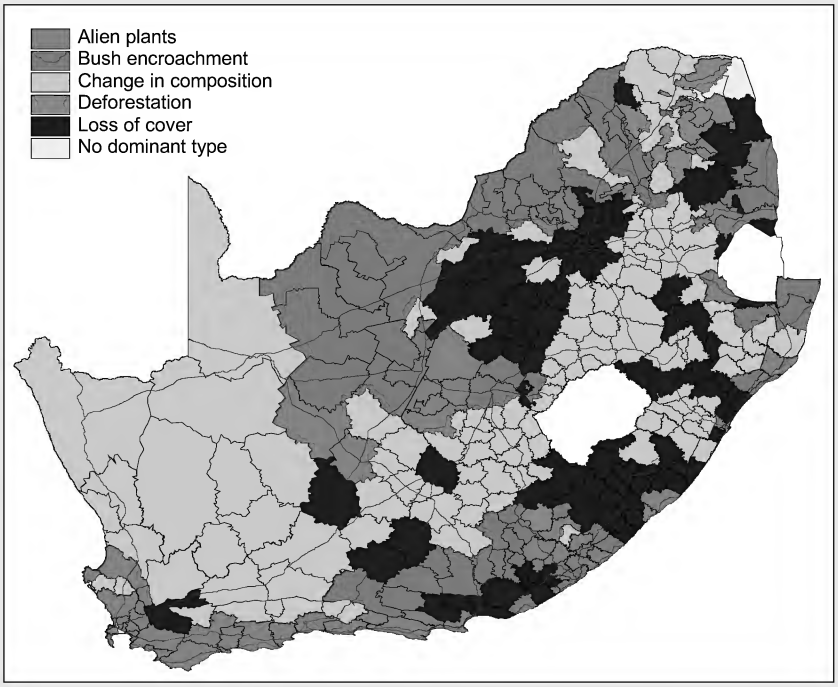

Figure A1 Types of habitat degradation perceived to be the first priority concern in each of the 367 magisterial districts—excluding Lesotho and Swaziland (from Hoffman & Ashwell 2000).

vegetation type in relation to its biodiversity target and thresholds for ecosystem functioning (see Figure 16.4). We recognise that our approach is very simplistic and that many other factors should be taken into account (such as habitat degradation). This represents one of the first attempts towards deriving an objective and defensible method for the identification of threatened ecosystems. It does not preclude the identification of additional threatened ecosystems based on, for example, an assessment of habitat degradation, when further spatial information becomes available. Similar assessments were conducted in the subtropical thicket biome (Cowling et al. 2003, Pierce et al. 2005) and in the United States based on the same factors (Noss et al. 1995).

Critically endangered vegetation types have been transformed to such an extent that the remaining habitat is less than that required to represent 75% of species diversity (i.e. the biodiversity target); in other words, one would expect species loss to take place in such vegetation types. Endangered vegetation types have lost up to 40% of their original extent and are exposed to partial loss of ecosystem function. Vulnerable vegetation types have lost up to 20% of their original extent, which could result in some ecosystem functions being altered (Figure 16.4). No significant disruption of ecosystem functioning is assumed in least threatened vegetation types, which still possess more than 80% of their original extent intact.

The status of two vegetation types could not be determined, namely Cape Vernal Pools and Pitketberg Quartz Succulent Shrubland (due to their small extent). Out of 433 vegetation types assessed, 19 are critically endangered, 53 endangered, 69 vulnerable and 292 least threatened.

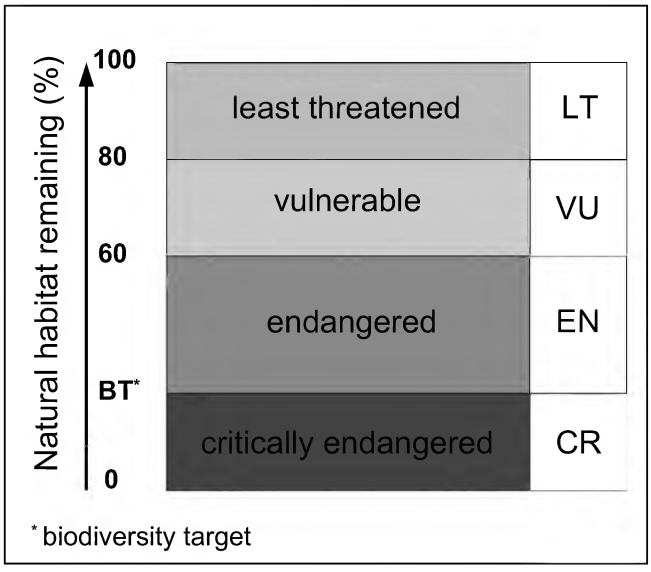

Figure 16.4 Classification of vegetation types into four levels of ecosystem status based on % of remaining untransformed area and the biodiversity target.

Table 16.4 Critically endangered vegetation types in South Africa, Lesotho and Swaziland. These were identified based on extent of habitat transformation and biodiversity target. For all of them, the percentage of remaining natural habitat is less than the required biodiversity target set to represent 75% of the plant species present in each vegetation type.

Vegetation type	Biome or azonal units	Remaining area (%)	Target (%)	Protected (%)
Lourensford Alluvium Fynbos	Fynbos Biome	7	27	4.2
Swartland Shale Renosterveld	Fynbos Biome	9	27	0.5
Swartland Silcrete Renosterveld	Fynbos Biome	10	27	0.6
Central Rûens Shale Renosterveld	Fynbos Biome	13	30	0.4
Western Rûens Shale Renosterveld	Fynbos Biome	14	30	0
Elgin Shale Fynbos	Fynbos Biome	18	29	5.9
Cape Flats Sand Fynbos	Fynbos Biome	19	25	0.1
Eastern Rûens Shale Renosterveld	Fynbos Biome	19	32	0.4
Swartland Granite Renosterveld	Fynbos Biome	20	27	0.6
Rûens Silcrete Renosterveld	Fynbos Biome	22	32	0.1
Peninsula Shale Renosterveld	Fynbos Biome	23	25	18.7
Swartland Alluvium Fynbos	Fynbos Biome	25	27	1.7
Woodbush Granite Grassland	Grassland Biome	26	27	0
Cape Lowland Alluvial Vegetation	Azonal Vegetation	31	32	0.7
Swamp Forest	Forests	95	100	100
Mangrove Forest	Forests	96	100	46.9
Lowveld Riverine Forest	Forests	97	100	100
Sand Forest	Forests	98	100	100
Ironwood Dry Forest	Forests	100	100	100

Due to the spatial bias of habitat transformation in South Africa, Lesotho and Swaziland (see Figure 16.3), critically endangered vegetation types, with the exception of forest types, are mostly concentrated in the Western Cape Province of South Africa (Figure 16.5). The forests and the Fynbos Biome have the greatest proportion of critically endangered vegetation types (see Figure 16.6). The Desert, Nama-Karoo and Succulent Karoo Biomes have the highest proportion of least threatened vegetation types. The grasslands have been considerably impacted by habitat transformation, and as a result, most of the grassland vegetation types are classified as endangered or at least as vulnerable (Figure 16.6). Critically endangered vegetation types are listed in Table 16.4.

It is unlikely that we have overestimated the ecosystem status of any vegetation type. However, the ecosystem status for some vegetation types is likely to be underestimated as habitat degradation was not taken into account. Many vegetation types currently classified as least threatened are degraded to a large extent. A more detailed spatial assessment of the extent of habitat degradation in southern Africa is required in order to derive a more accurate ecosystem status of vegetation types.

5. Protection Level

Currently, 6.25% of South Africa, Lesotho and Swaziland is under protection. This includes statutory reserves (national parks, provincial and local authority nature reserves) and nonstatutory reserves (such as mountain catchment areas and private nature reserves) with a much less secure conservation agreement. The conservation estate consists of 465 statutory protected areas (representing 77% of the total protected area) and 508 non-statutory protected areas (Figure 16.7). Only few protected areas are greater than 100 000 ha; most of them are between 1 000 and 10 000 ha (Figure 16.8). The implications of the size

of protected areas for conserving biodiversity have been discussed elsewhere (Schwartz 1999; see Rebelo 1997 for a review on southern Africa) and will not be addressed here. While concern has been raised that small protected areas might be inadequate for maintaining large-scale processes (such as natural fire regimes), they do play an important role in conserving some of the last remaining fragments of lowland vegetation types.

In assessing the protection levels of vegetation types, it would be ideal to include some measure of management effectiveness within protected areas. However, it is unlikely that we will ever have a national dataset that provides widely endorsed information of this kind. In the absence of information about management effectiveness, legal status and ownership must suffice as a way of distinguishing categories of protected areas.

With only 6.2% of the land protected, most of South Africa, Lesotho and Swaziland is not adequately conserved (Figure 16.9). As biodiversity and protected areas are not uniformly distributed in the landscape, huge gaps appear in the protected area network. In terms of biome representation, the Forest, Fynbos and Desert are the most protected biomes (in terms of percentage of total area), while the Nama-Karoo and Grassland are the least protected biomes (Table 16.1). An assessment of the protection levels of each vegetation type in relation to their biodiversity targets reveals that 116 vegetation types have no form of protection at all (Figure 16.9). It is important to note that this assessment focuses on representation of biodiversity pattern, and that larger areas will be required for conserving critical ecological and evolutionary processes. Furthermore, an additional 79 vegetation types, with only < 5% of their biodiversity target protected, are hardly protected. More than 300 vegetation types have less than half of their biodiversity target conserved in statutory protected areas. Only 65 vegetation types have their biodiversity targets met in statutory protected areas, including 24 types of Fynbos, 24 of Savanna and seven of Grassland.

In order to meet the biodiversity targets for all vegetation types, at least an additional 215 000 km^2 would have to receive some form of conservation action. This amounts to 20% of the remaining natural habitat in South Africa, Lesotho and Swaziland.

Protection level can and should inform priorities for the establishment and expansion of protected areas. Based on the principle of representation, vegetation types not adequately represented in the current protected area network should receive priority attention. However, we need to note strongly that the establishment of formal protected areas is not the only form of conservation action possible. Especially in vegetation types that are highly fragmented, conservation action may include, for example, working with industry and local government to ensure conservation-friendly land use in priority areas. Used in conjunction, measures of ecosystem status and protection level are very useful for identifying priority vegetation types in need of conservation action of some kind. Ecosystem status tells us which vegetation types are most threatened, while protection level tells us which vegetation types are least protected. For example, it is clear that the Knysna Sand Fynbos or the Rûens

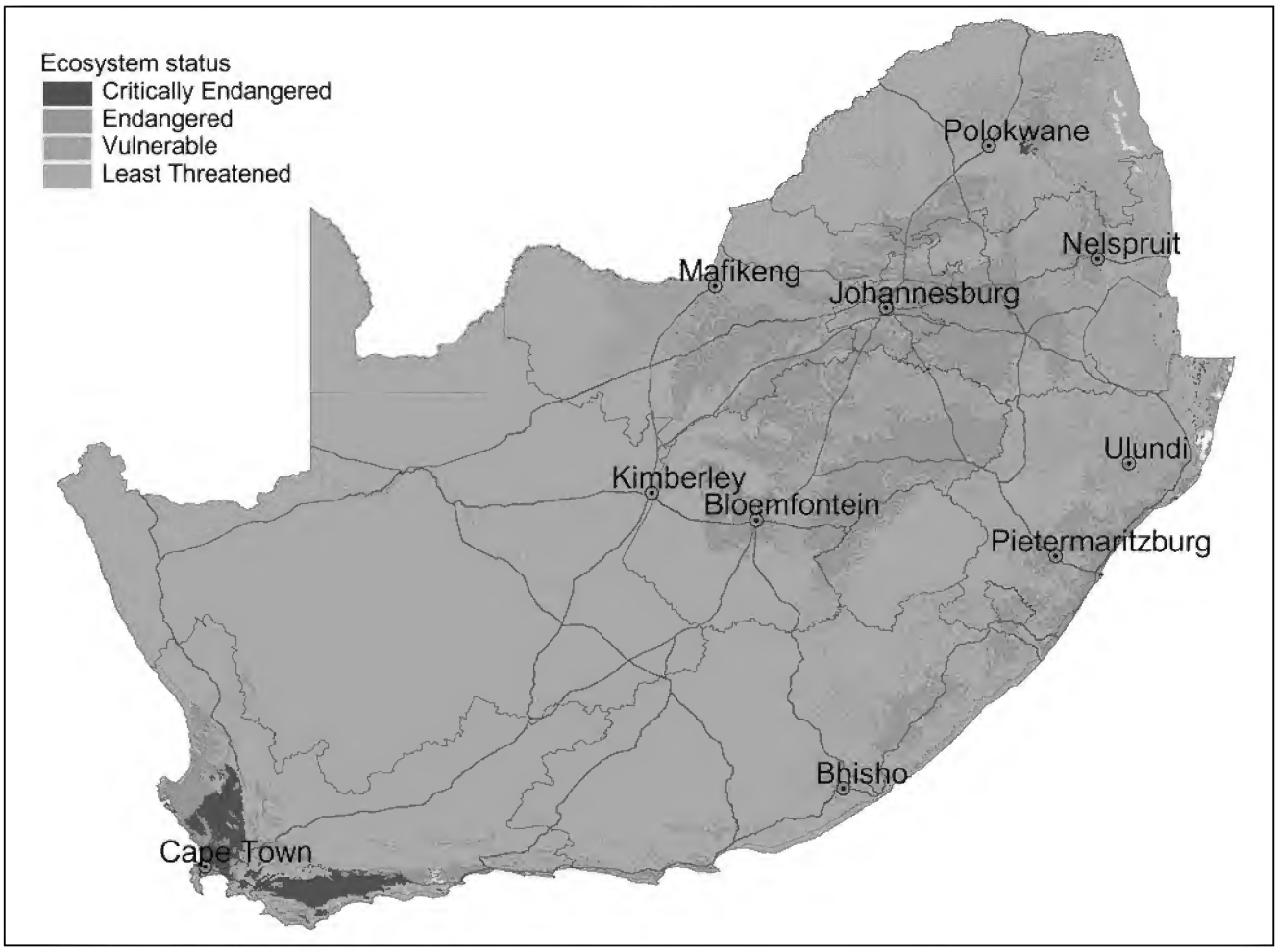

Figure 16.5 Ecosystem status of vegetation types. Vegetation types were classified into critically endangered (CR), endangered (EN), vulnerable (VU) and least threatened (LT) based on habitat transformation pattern and biodiversity targets.

Silcrete Renosterveld, which are critically endangered *and* not represented in the current protected area network, have not received adequate conservation efforts.

However, while the implementation of conservation plans can take quite some time and when conservation budgets are limited, scheduling of conservation actions becomes important. It has been proposed that scheduling should consider a measure of conservation value and vulnerability to future land use pressures (What is the likelihood of losing this area of natural vegetation in the near future?) (Pressey & Taffs 2001; see chapter on Vulnerability).

6. Conservation Priorities

Setting conservation priorities is a complex task (see Box B). One has to integrate biodiversity pattern and process as well as consider future pressures due to other land uses. Few conservation

Box B: Species or land class biodiversity features?

Conservation targets can be divided into two broad categories based on the scale of biodiversity surrogate targeted (Pressey et al. 2003). Coarse-filter approaches set targets for features such as vegetation types, ecosystems or land-classes. Fine-filter approaches use species or populations as the focal feature for conservation action. While the two approaches are complementary, for most regions limitations in species distribution datasets obligate the use of coarse-filter surrogates (Lombard et al. 2003).

Vegetation or land-class maps, such as this vegetation map, have the advantage of covering the entire landscape, thereby eliminating the inherent spatial and taxonomic bias of species datasets (Lombard et al. 2003). There are limitations when using such maps. Firstly, reserve selection using the coarse-filter approach is likely to protect many species for which records are deficient or are yet to be discovered. However, unless complementary fine-filter information is incorporated in the process, other species, especially rarer ones, are likely to be missed (Kirkpatrick & Brown 1994; Lombard et al. 2003). Secondly, the spatial, land-class compositional or process requirements of certain species are unlikely to be satisfied unless specifically targeted. Thirdly, land classes do not explicitly target natural processes. These need to be targeted separately if biodiversity is to persist (Cowling et al. 1999; Cowling & Pressey 2001).

These problems are compounded by problems relating to scale. Targets framed as percentages of countries or regions can be achieved while failing to protect the natural features most urgently in need of protection (Pressey et al. 2003). Large regions are heterogeneous in terms of biodiversity and potential for anthropogenic transformation. Conservation areas have often been relegated to the least useable portions of regions, thereby avoiding areas where past impacts on biodiversity have been greatest and future threats are most serious (Pressey et al. 2000, Scott et al. 2001). This is true even of regions with overall percentages under formal protection equal to or greater than 10%. Also, coarse-scale maps do not capture all possible land-class combinations, so even if vulnerability over the whole area is low, certain landscape biodiversity features (e.g. rare vegetation types or habitats) can fall through the cracks. These issues can be addressed by mapping at finer scales and with improved mapping techniques (Ferrier et al. 2002). Targeting better mapped land types with classes that are more homogeneous in terms of biodiversity and land use potential, limits the potential for conservation action to miss capturing all biodiversity (Bedward et al. 1992). To this end the new vegetation map represents a more fine-scale interpretation of the vegetation patterns, and more broadly, biodiversity patterns encountered within Southern Africa.

Mindful of these limitations, it must be accepted that for most areas on this planet, land-class maps of some sort will be the primary biodiversity feature used for conservation and land use planning.

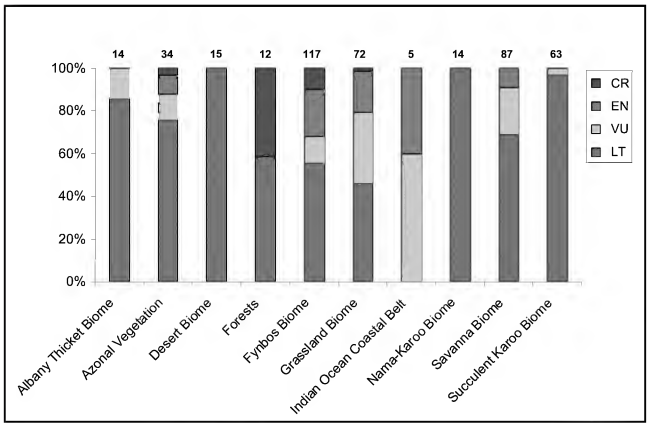

Figure 16.6 Proportion of critically endangered (CR), endangered (EN), vulnerable (VU) and least threatened (LT) vegetation types per biome. The number of vegetation types present in each biome and in azonal vegetation is indicated on top of the bars.

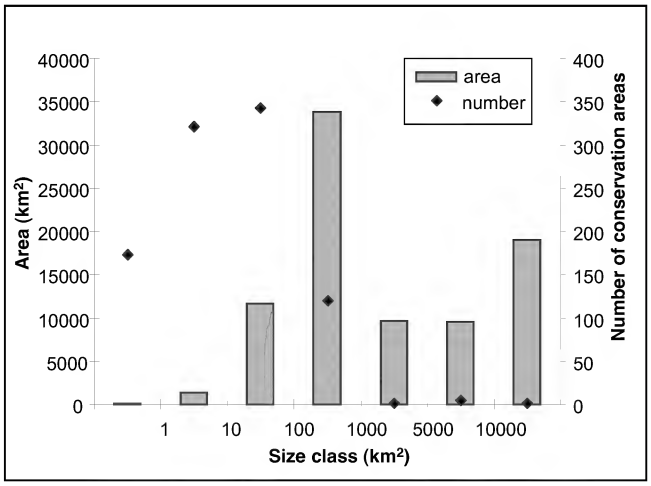

Figure 16.8 Size-class distribution of the protected area network for South Africa, Lesotho and Swaziland.

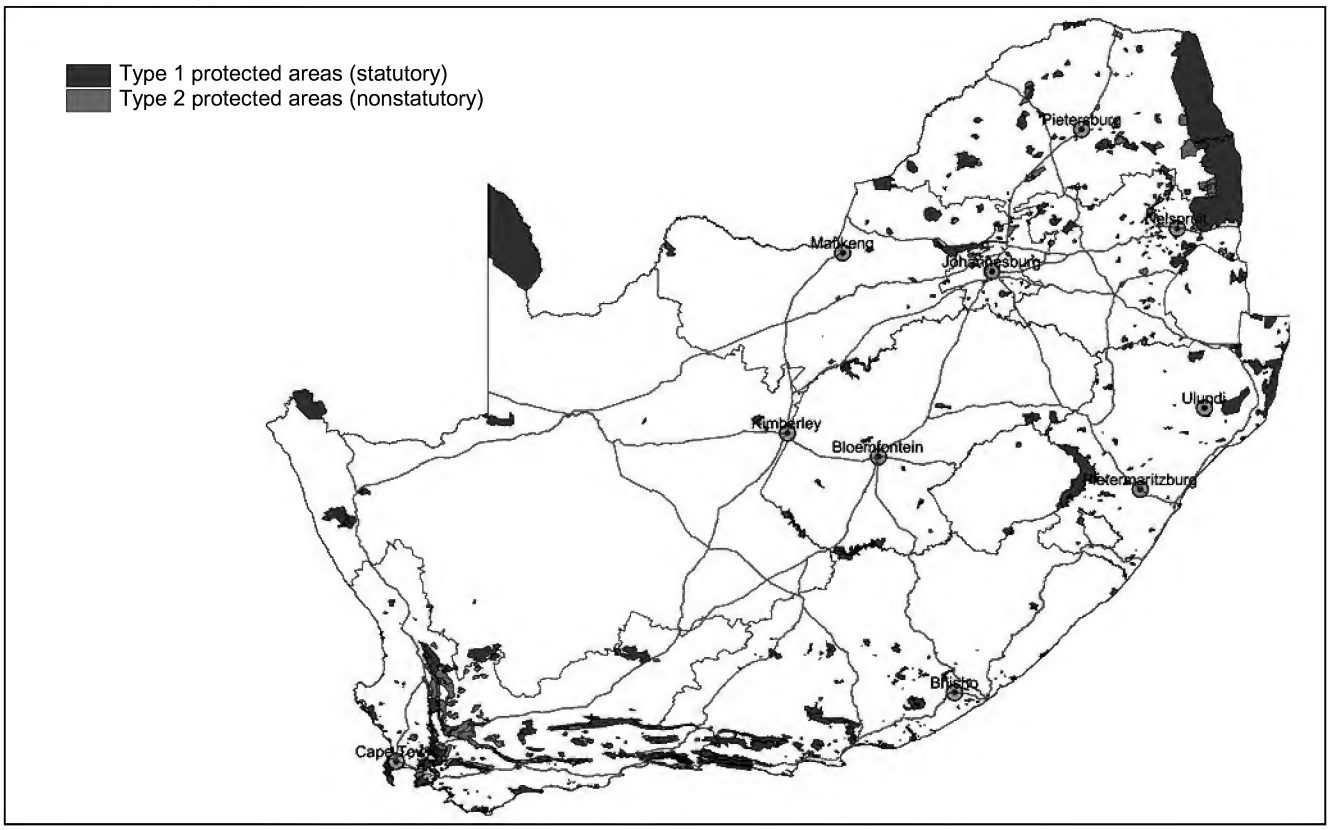

Figure 16.7 Protected area network in South Africa, Lesotho and Swaziland. Protected areas are classified into two types: statutory (type 1) and nonstatutory (type 2) based on ownership and legal status.

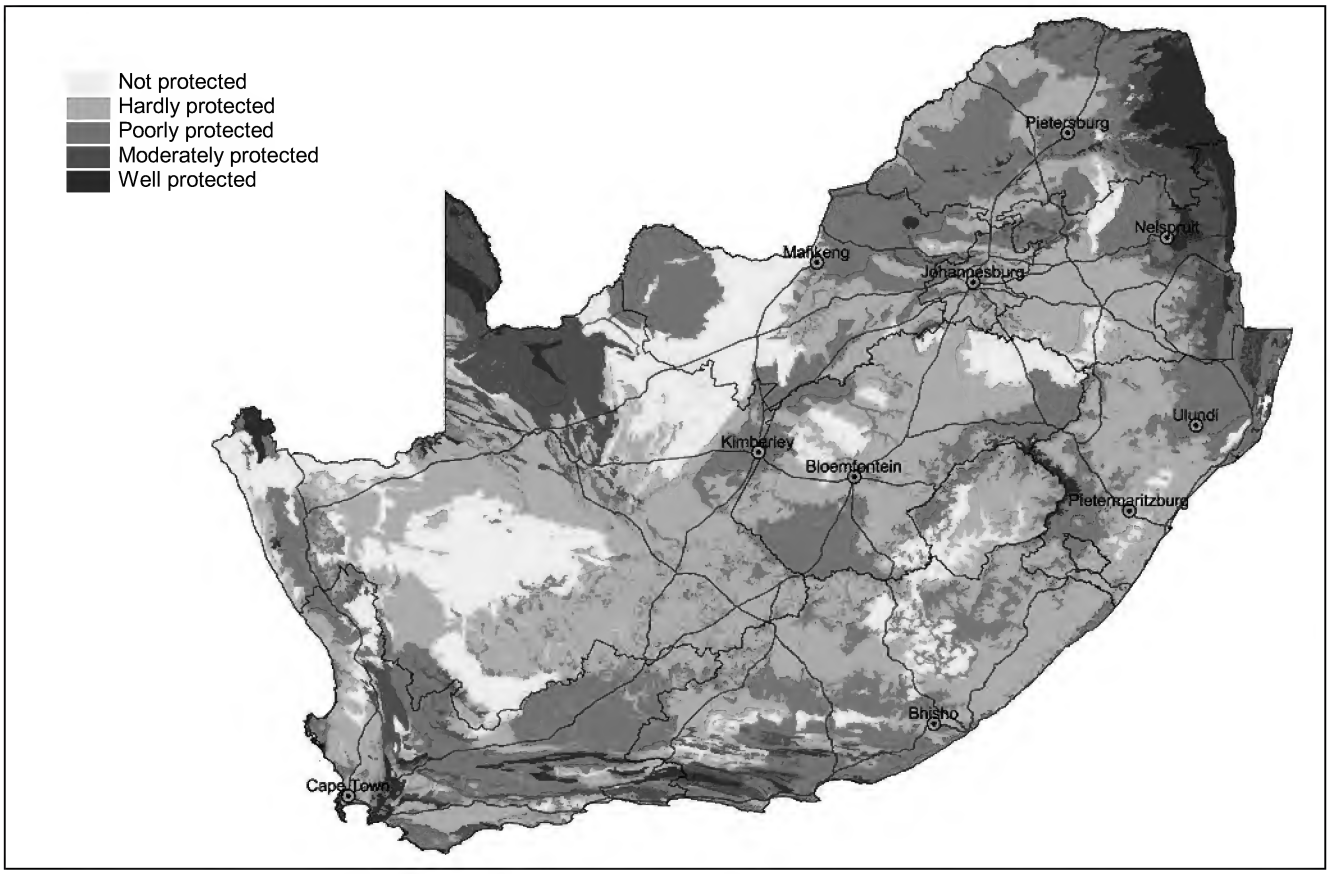

Figure 16.9 Protection levels of vegetation types based on the proportion of biodiversity target set for each vegetation type represented in statutory protected areas. Not protected (0% of biodiversity target protected in statutory protected areas), hardly protected (< 5% of the biodiversity target protected), poorly protected (< 50% of the target protected), moderately (< 100% of the target protected), well protected (biodiversity target protected in statutory protected areas).

assessments have managed to do this successfully. Trade-offs tend to occur as areas required for achieving pattern and process often do not overlap. Therefore different geographical priority areas can be identified by focusing on habitats, species of special concern or biodiversity processes.

In the National Spatial Biodiversity Assessment (NSBA, see Driver et al. 2005), due to the mismatch of scale between the various analyses (e.g. ecosystem status at the vegetation type scale, habitat irreplaceability at a sixteenth-degree scale, species irreplaceability at a quarter-degree scale), all analyses could not be combined into one overall 'irreplaceability' measure. A scoring system was developed whereby each separate analysis (e.g. ecosystem status, species irreplaceability) was scored. This enables one to combine all these analyses and identify priority areas for habitat, species and processes. Multi-criteria approaches, when used in conservation assessments, have been criticised because they are often not systematic and do not satisfy the principle of representation or persistence. The products of the NSBA (ecosystem status, protection levels of ecosystems, analysis of species of special concern, and national-scale ecological processes) are systematic and fulfil the goals of representation and persistence. The NSBA simply used a scoring approach for prioritising areas based on systematic conservation assessment products. As there is a potential danger of mixing criteria of different kinds together in a scoring approach, priority scores (and priority areas) were first identified for habitat, species and process separately, and then combined to identify overall priority areas. The priority areas thus identified are also priority areas for habitat, species or process, and not an area averaging medium score for all criteria.

Here we focus on priority areas identified for habitat only (i.e. vegetation types). One should bear in mind that other areas might be crucial for maintaining ecological and evolutionary processes (see Figure 16.10), or for species representation.

We combined three analyses to identify priority areas for habitat: ecosystem status, protection levels and irreplaceability (see Box C). Irreplaceability quantifies the contribution of a site to achieve biodiversity targets, in other words, to ensure the representation of biodiversity features (Ferrier et al. 2000). Irreplaceability values range from 0 (site not required to achieve biodiversity targets) to 1 (irreplaceable site, target cannot be achieved without it). We calculated irreplaceability values based on biodiversity targets set for vegetation types, wetlands and estuaries (see Box C). We used sixteenth-degree squares (approximately 4 400 ha) to calculate irreplaceability.

Ecosystem status was scored from 0 to 100 as follows: critically endangered vegetation types were assigned a score of 100; endangered vegetation types, 75; vulnerable vegetation types, 50; and least-threatened vegetation types, 25. Protection levels of ecosystems were scored as follows: well-protected vegetation types (100% or more of the target is achieved in statutory protected areas) were assigned a score of 0; nonprotected vegetation types, 100; and for other vegetation types, the score was 100 minus the percentage target achieved in statutory protected areas (e.g. if a vegetation type has 10% of its biodiversity

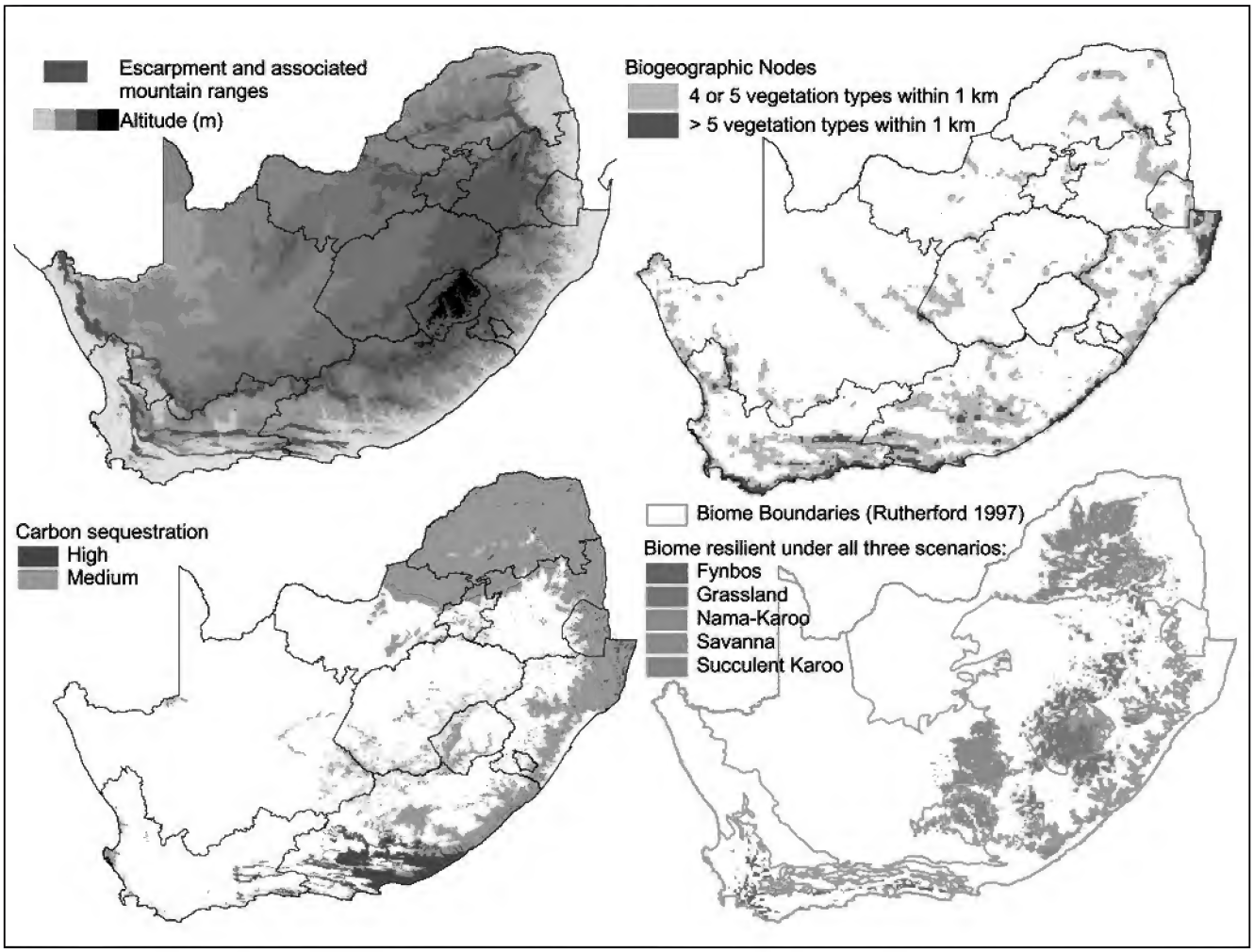

Figure 16.10 National-scale ecological processes, represented by (a) the Great Escarpment and associated mountain ranges, (b) biogeographic nodes, (c) carbon sequestration areas and (d) areas of biome resilience to climate change.

Box C: Irreplaceability analysis for vegetation types, estuaries and wetlands

The concept of representation underpins most conservation assessments (Margules & Pressey 2000, Driver et al. 2003). Conservation planners seek to identify areas that will represent an appropriate sample (defined by the biodiversity targets) of each biodiversity feature. Irreplaceability quantifies the contribution of a site to achieve biodiversity targets, in other words, to ensure the representation of biodiversity features (Ferrier 2002). Irreplaceability values range from 0 (site not required to achieve biodiversity targets) to 1 (irreplaceable site, target cannot be achieved without it).

The irreplaceability measure applies to sites (and not directly to biodiversity features).

Based on vegetation types (and estuaries and wetlands from a separate study, see table below), we calculated irreplaceability values for the 31 130 planning units using the software C-Plan (Ferrier et al. 2000).

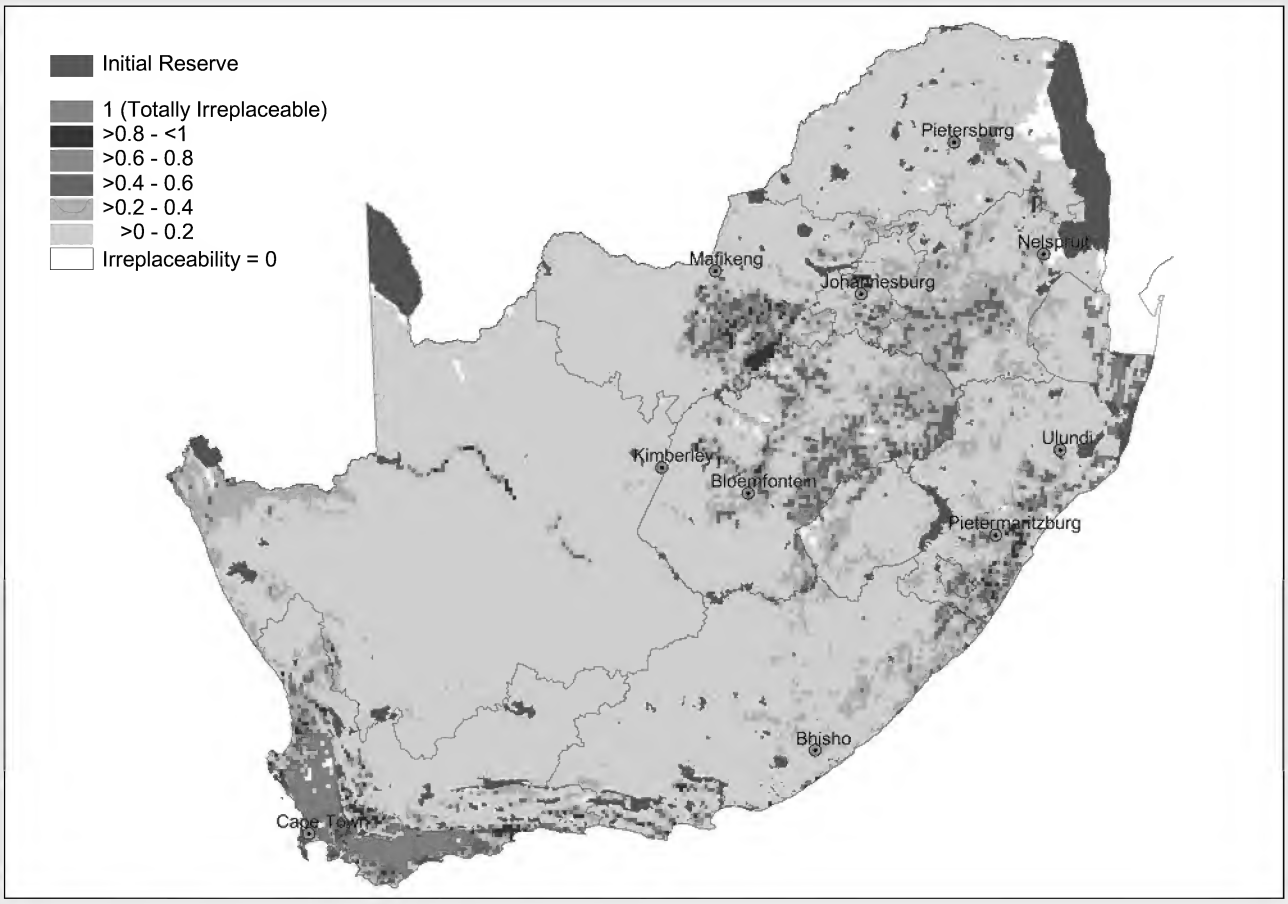

Figure C1 Irreplaceability pattern for vegetation types, estuaries and wetlands.

Most of South Africa's land surface appears to have low irreplaceability values (< 0.4), meaning that there are still many options for achieving biodiversity representation targets for many vegetation types (or estuaries or wetlands) (Figure C1). 790 sites representing 1% of South Africa's remaining habitats are irreplaceable. A further 0.6% has high irreplaceability values (> 0.8). A site could be irreplaceable for two reasons: (a) severe habitat transformation has reduced the amount of remaining habitat close to the target (the case for critically endangered vegetation types); and/or (b) the biodiversity target is quite high (the case for some forest or estuary types). Options to achieve biodiversity targets are limited in places where habitat transformation has been most severe (see Figure C1 and compare it with Figure 16.3). In other words, our ability to achieve biodiversity representation targets is influenced more by habitat transformation than the biodiversity target itself.

List of biodiversity features included in the irreplaceability analysis (SANBI, South African National Biodiversity Institute; DEAT, Department of Environmental Affairs and Tourism)

Biodiversity feature	Source	Number	Target range
Vegetation types	SANBI	438 types	12–100% of original area
Estuaries	DEAT	16 types	At least 3 or 20% of each type
Wetlands	DEAT	17 types	At least 3 or 20% of each type
Wetlands & estuaries of significant importance	DEAT	1 type	100%

target achieved in statutory protected areas, the score was 90). For habitat irreplaceability, we applied the following score to each planning unit: 100 × irreplaceability value.

Due to different scales, all layers were converted to a grid of sixteenth-degree cell size to match the planning unit layer. Each cell was assigned a score for ecosystem status, protection levels and irreplaceability. These three scores were averaged and ranged from 0 to 100 (maximum score for all three criteria). Priority areas for habitat conservation were defined as cells where the average score was greater than 60.

Figure 16.11 shows the priority areas identified for conserving biodiversity at the habitat level. Three main priorities emerged: the Cape lowlands (lowland part of the Southwest Fynbos Bioregion, and the West Coast Renosterveld and East Coast Renosterveld Bioregions), the central grasslands (Mesic Highveld and Dry Highveld Grassland Bioregions), and part of the Indian Ocean Coastal Belt and the Sub-Escarpment Savanna Bioregion in KwaZulu-Natal. Most of the Nama-Karoo Biome appears least transformed. However, this could be due to the lack of fine-scale spatial information on habitat degradation.

These habitat priority areas differ from those identified on the basis of species distribution pattern or ecological processes (see Driver et al. 2005). On the basis of habitat alone, the Succulent Karoo and the Albany Thicket do not emerge as a priority. However, both are national priority areas identified by the National Spatial Biodiversity Assessment (Driver et al. 2005).

7. Conclusion

What are the implications of these results for conservation action in South Africa, Lesotho and Swaziland? Perhaps the main implication is that conservation action cannot be limited to the establishment or expansion of 'traditional' large protected areas. Clearly, protected areas represent a major conservation instrument and we need more (in the Grassland Biome for example), but they might not be appropriate in every situation. The remaining natural habitat in critically endangered and endangered ecosystems is likely to be fragmented and situated in a matrix of productive agricultural, industrial and urban land uses, making the establishment of protected areas impractical. This means that the conservation sector needs to engage proactively with industry, civil society and local government in areas where there are concentrations of critically endangered and endangered ecosystems. Curtailing further loss of natural habitat in these areas, and the associated loss of ecosystem functioning and species, will involve making the case to major land users and decision-makers that retention of biodiversity is part of maintaining national ecological infrastructure. It could involve the development of industry-specific biodiversity guidelines, in close partnership with industry bodies, to guide decisions about how land is used and managed. The incorporation of spatial biodiversity priorities into land use planning and environmental assessment processes at municipal and provincial level can provide a powerful way to protect critically endangered and endangered ecosystems.

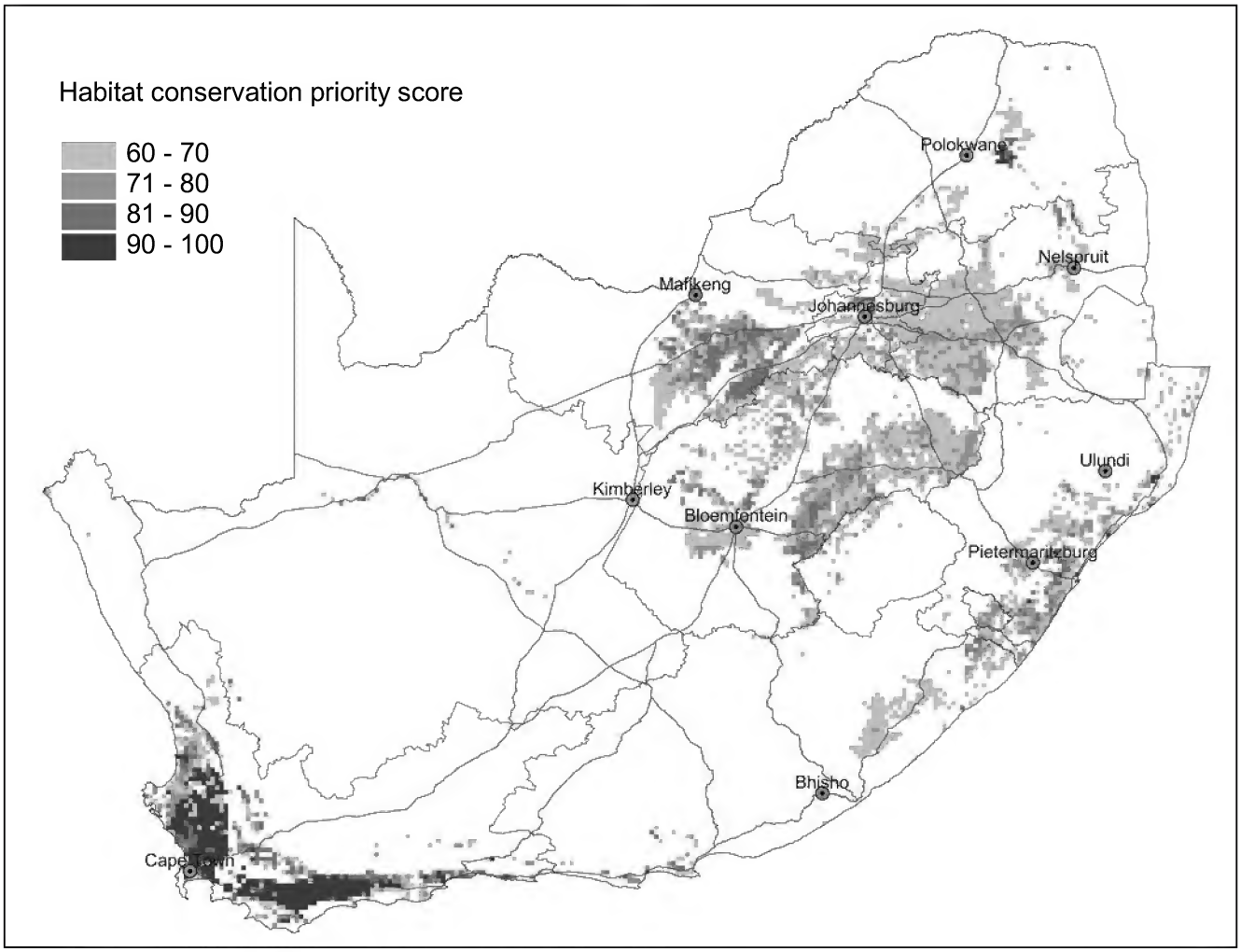

Figure 16.11 Priority areas for conserving habitat based on ecosystem status, protection levels and irreplaceability surface. The colour gradient refers to the priority score.

8. Credits

The unpublished version of the vegetation map used for this analysis was provided by M.C. Rutherford and L. Mucina. The GIS data were provided by L.W. Powrie. Some tables and figures were adjusted for presentation by L.W. Powrie. The National Land Cover was provided by the CSIR, and information on protected areas by DEAT and all provincial conservation agencies. Biodiversity targets were calculated by P.G. Desmet and R.M. Cowling. Most analyses were performed by Z. Jonas and M. Rouget. B. Mohamed assisted with some GIS analysis. M. Rouget was the lead author and R.M. Cowling, P .G. Desmet and A. Driver provided substantial input and editing on earlier drafts. P.G. Desmet wrote the section on targets. L. Mucina and M.C. Rutherford provided final editorial comments. Valuable scientific and technical input was received from conservation planners who were involved in the National Spatial Biodiversity Assessment.

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Vulnerability Assessment of Vegetation Types

17

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Figure 17.1 A small patch of shale fynbos surrounded by expanding upmarket suburbs in Gordon's Bay (Western Cape) at the foot of the Hottentots Holland Mountains. Populations of two local proteoid endemics (*Leucospermum bolusii* and *Paranomus spicatus*) share this vacant lot with other rare fynbos flora.

L. Mucina

1. Introduction

Humans have transformed almost half of the world's land surface area into agriculture and urban systems (Chapin et al. 2000). The most severe biodiversity loss occurs when a natural ecosystem is converted to an artificial system (Geneletti 2003). This does not only affect ecosystems by altering their composition and processes, but also has important consequences for water supply and other ecosystem services upon which humans depend (Kunin & Lawton 1996, McCann 2000). Land conversion can be due to several causes, e.g. agriculture, urbanisation, road development and deforestation. When the land is converted from a natural or semi-natural state to one of these forms of land cover, many species are unable to persist (Dale et al. 1994) as a result of direct and indirect loss of habitat.

Mapping expected future loss of natural habitat or ecosystem function can be very useful in scheduling implementation of conservation actions. Focusing first on areas of high biodiversity value that are also highly vulnerable to future habitat loss or degradation is usually recognised as the most effective way to minimise biodiversity loss (Pressey 2004).

South Africa is one of the top 25 countries in the world in terms of biodiversity (WCMC 1992), with a greater part of its biodiversity occurring on agricultural land than in current conservation areas. Due to the expansion of cropland or urban areas, some of that biodiversity will be lost in the near future (Wessels et al. 2000).

Few studies done at different scales have outlined the land use pressures in South Africa (Wessels et al. 2003). This assessment focuses on the potential loss of natural habitat due to habitat transformation and degradation processes, which will threaten the biodiversity of the area. These processes can be land use-related where untransformed areas with a high suitability to a particular land use (e.g. cultivation, afforestation) are highly vulnerable. In these areas, not only natural habitat will be lost, but the species composition can also be completely altered. Alternatively these processes may be linked to the modification or degradation of biodiversity pattern and processes of an area (e.g. alien invasion and habitat fragmentation). These processes may not necessarily lead to complete loss of natural habitat, but do modify the composition of an area sufficiently to threaten ecosystem function.

We refer to the potential loss of natural habitat or ecosystem function defined above as vulnerability. In this assessment, two classes of vulnerability are referred to as *land use vulnerability* (population growth, land capability—dryland agriculture, afforestation and mining) and *degradation vulnerability* (habitat fragmentation and alien plant invasion). Vulnerability was summarised for each vegetation type.

The objective of this chapter is to describe the relationship between biodiversity pattern (defined by 433 of the 435 mainland vegetation types—two were too small for analysis), landscape structure and land use pressures in natural habitats of South Africa and to interpret this relationship in terms of vulnerability.

2. Approach

In this assessment we used several databases (see Box A) to quantify the vulnerability of vegetation types to a suite of future pressures in order to identify vegetation types of concern. We mapped and quantified land use vulnerability based on land capability, afforestation potential, mining potential and population growth. We also mapped and quantified degradation vulnerability based on habitat fragmentation and alien plant invasion. Fine-scale habitat degradation (related to over-grazing, bush encroachment, over-harvesting of natural resources) has not been mapped comprehensively for South Africa. The only information available was the assessment done by Hoffman & Ashwell (2000) at a district level. Due to the coarse scale, this could not be used for assessing the degradation status of vegetation types. However, such information can be used at the scale of the priority areas identified by the National Spatial Biodiversity Assessment (Driver et al. 2005).

All the vulnerability layers were rasterised using a 100 m cell size. For each vulnerability type, vulnerability was scored from 0 (not vulnerable) to 100 (highly vulnerable). Each layer thus had a very low vulnerability class (0–25), a low vulnerability class (25–50), a medium vulnerability class (50–75) and a high vulnerability class (75–100). Care was taken to ensure that all re-scaled values represented the original vulnerability classes well.

In order to produce one layer on vulnerability across the country, we needed to combine these various datasets. All the datasets, with the exception of the mining potential, were continuous datasets and could therefore be combined arithmetically. Combining multiple threats raises several challenges, e.g. whether an area susceptible to more than one threat is more vulnerable than one susceptible to only one threat.

We produced two sets of vulnerability indices. One was an average vulnerability score for each 100 × 100 m grid cell across the country based on all vulnerability layers. This product would thus highlight areas vulnerable to a large number of future pressures. For areas currently untransformed within each vegetation type, we calculated the average score for each vulnerability type (degradation and land use). The degradation vulnerability layer was derived using the average per grid cell of the alien plant invasion and habitat fragmentation layers (see later in Habitat Fragmentation section). Land use vulnerability was derived using the average per grid cell of the land capability, afforestation and population change layers. An overall vulnerability index was calculated by averaging land use and degradation vulnerability. Vulnerability to climate change was not considered.

The second was a map of all areas in the country, which are highly vulnerable to any threat. This highlights highly vulnerable areas irrespective of the number of pressures. The raster layers produced for each type of vulnerability were used to extract areas of high vulnerability to any pressure. Pixels with a vulnerability of higher than 75 for afforestation, land capability, mining, population change, habitat fragmentation and alien plant invasion were extracted and combined to produce maps of high future pressures. Vulnerability to land use and to habitat degradation were differentiated.

In order to identify the degree of vulnerability of each vegetation type, we then summarised the average vulnerability value and the percentage of the natural area under high pressure per vegetation type.

3. Land Use Vulnerability

3.1 *Land capability*

Land capability reflects the land suitability to crop production and also to other less intensive uses such as pasture, natural grazing, forestry and wildlife (see Figure 17.2). Land capability was modelled based on soil and terrain features and climate of an area. Low nutrient status was not considered a limitation,

Box A: Description of the databases used to derive vulnerability layers in South Africa.

Several databases on vulnerability are available in South Africa at a national scale. These databases were investigated and either selected for the analysis or discarded based on characteristics in the database. Table A1 provides a list of these databases and reasons for their selection or rejection.

Table A1 Various datasets used in the vulnerability assessment.

Database	Source	Description	Limitations	Used
Land use vulnerability				
Land capability	ARC (ISCW)	Total suitability for use, in an ecologically sustainable way, for crops, grazing, woodland and wildlife	Mapped at a broad scale	Yes
Grazing potential	CSIR	Areas which have the potential to support a similar number of herbivores per unit land area	Does not imply pressure unless poorly managed	No
Afforestation	CSIR	Potential for pine and eucalypt species based on bioclimatic variables	Only mapped for some provinces (LP, MP, KZN, EC, WC)	Yes
Mining	Council for Geoscience	Mapped mineral deposits, fields, layers and provinces	Categorical data	Yes
Population growth	StatsSA	Change in population density per municipality from 1996 to 2001 census products	Broad units of municipalities	Yes
Degradation vulnerability				
Fragmentation				
Landscape resistance	NLC	Incorporates connectivity and surrounding land uses		Yes
Extent of natural habitat	NLC	Area of untransformed habitat		Yes
Fragment size	NLC	Size of remaining habitat		Yes
Plant invasion	SANBI/ CSIR	Numbers of alien invasive species that could occur in a region		Yes
Degradation	Hoffman & Ashwell (2000)	Soil and vegetation degradation per magisterial district	Very broad units for vegetation analysis	No

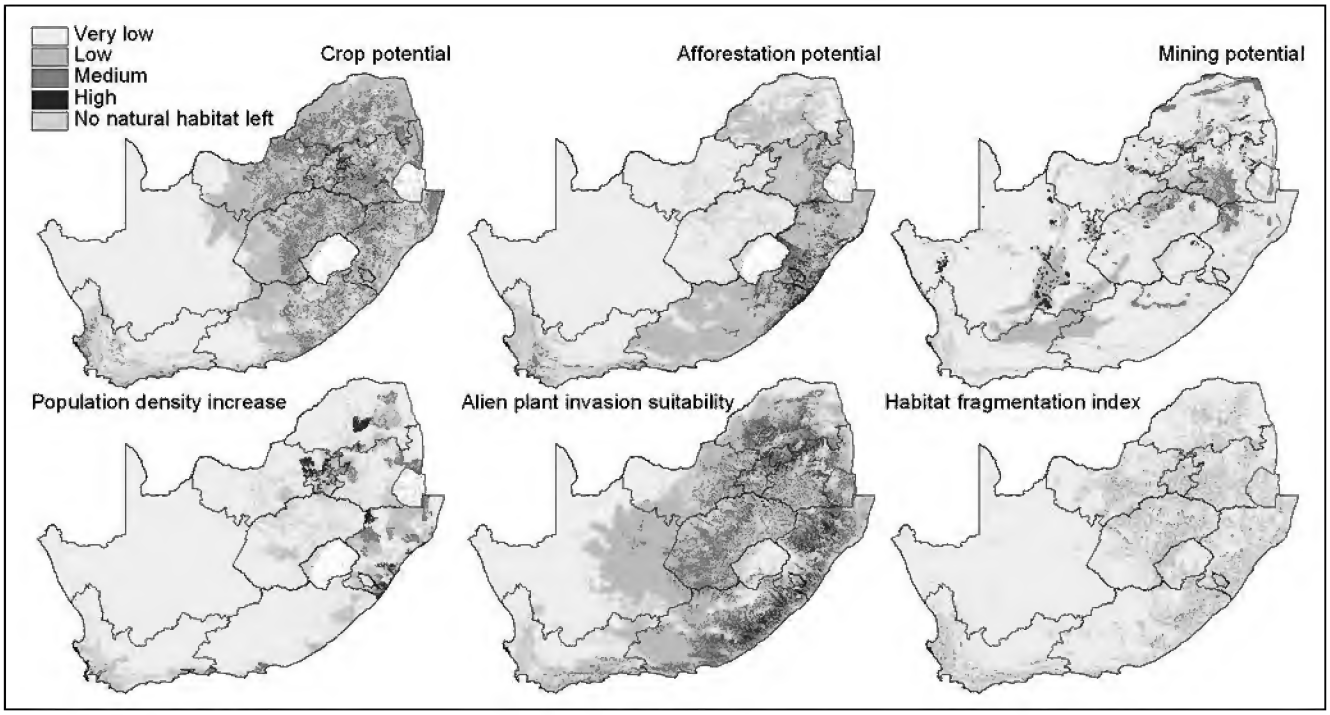

Figure 17.2 Vulnerability to future land use change (crop potential, afforestation potential, mining potential, population density increase) and habitat degradation (alien plant invasion suitability and habitat fragmentation index) in South Africa.

since it is assumed that inherent nutrient deficiencies/toxicities will be rectified by appropriate liming and/or fertilisation. The land capability classification system applies only to rain-fed agriculture. Land suited to crop production is also suited to other less intensive uses such as pasture, natural grazing, forestry and wildlife. Most of the conversion of natural habitats with a high agricultural production potential to cultivated areas took place in the last 50 years and has considerably reduced the extent of several vegetation types. These vegetation types are mostly communities of the Grassland Biome (Macdonald 1989) and Renosterveld shrublands of the Western Cape, which presently occupy a fraction of their original range (Heydenrych & Littlewort 1995).

Land capability potential, averaged per vegetation type, varies quite considerably. Out of 433 vegetation types, 189 vegetation types have very low land capability; 180 vegetation types, low; 64 vegetation types, medium; and no vegetation types have high land capability. The top six vegetation types that are under medium land capability pressure include the Eastern Highveld Grassland, Tembe Sandy Bushveld, Swartland Alluvium Renosterveld, Maputaland Wooded Grassland, Western Maputaland Sandy Bushveld and Makatini Clay Thicket.

3.2 Afforestation Potential

Afforestation is the planting of trees for commercial purposes, usually on land supporting non-forest veld types, e.g. grassland or fynbos. Afforestation potential maps were modelled using fuzzy tolerance models, based on bioclimatic parameters. The bioclimatic factors used in these models were soil, rainfall and temperature (Fairbanks 1995). Although these maps were only generated for five provinces in South Africa, these provinces were found to coincide well with the areas suitable for wood production across southern Africa and thus the layer could be used in a national assessment. Each 1 km^2 grid was assigned an average suitability value for pine and eucalypt species. These values ranged from 0 (low suitability) to 100 (very high suitability) (Figure 17.2).

Natural habitats most severely affected by current afforestation include wetlands, grasslands, fynbos and indigenous forests (Heydenrych & Littlewort 1995). Based on this afforestation model (see Figure 17.2), 238 vegetation types have very low afforestation potential; 136 vegetation types, low; 52 vegetation types, medium; and seven vegetation types have a high afforestation potential. The top six vegetation types highly threatened by afforestation are the Pondoland-Ugu Sandstone Coastal Sourveld, Mangrove Forest, KwaZulu-Natal Sandstone Sourveld, Southern KwaZulu-Natal Moist Grassland, Midlands Mistbelt Grassland and Northern Escarpment Afromontane Fynbos.

3.3 Population Density Change

Due to the lack of data on urban and peri-urban sprawl in South Africa, we decided to use the change in population density as an indicator of human pressure. Data from the national censuses in 1996 and 2001 were used for this purpose. Both datasets were aggregated to the municipality level from the original enumerator areas. The difference in population between the two census periods was used to calculate the change in population density. This change in density is mostly related to the movement of people across the country towards urban areas, as well as natural population growth. Each municipality was thus assigned a value of the change in population density, which ranged from 19 to 356 people per km^2 and re-scaled from 0 to 100 (Figure 17.2).

From this assessment, 343 vegetation types occur in areas with very low population growth, 71 vegetation types in areas with low population growth, 12 in areas with medium population growth and seven in areas with high population growth. The top six highly threatened vegetation types are the Egoli Granite Grassland, Peninsula Granite Fynbos, Peninsula Shale Renosterveld, Peninsula Sandstone Fynbos, Lourensford Alluvium Fynbos and Cape Flats Sand Fynbos.

3.4 Mining Potential

No layer was readily available for mapping mining potential; Box B describes how we used mining resource field to map and categorise mining potential. Mining potential was determined based on the accuracy of the deposit mapping, its size, and the type of commodities. For example, areas of high mining potential consist of large mines/deposits or mineralised fields for 13 economically important commodities (Figure 17.2).

Mining potential is concentrated in few parts of the country (such as the West Coast) with only 2.1% of the whole country (1.8% of the untransformed natural habitats) under high mining potential.

Due to its categorical nature, mining potential could not be averaged per vegetation type. Instead we calculated the percentage of the untransformed area of each vegetation type of high mining potential. There are 195 vegetation types with no mining potential. A total of six vegetation types have 50% of their natural area occurring in medium mining potential areas and another four have 50% of their natural area occurring in high mining potential areas (see Table 17.1). The vegetation types most vulnerable to mining are: Namib Seashore Vegetation, Richtersveld Coastal Duneveld, Northern Escarpment Dolomite Grassland and Subtropical Seashore Vegetation.

Box B: Mining potential in South Africa.

The mining dataset was obtained from the Council for Geoscience.

It includes mineral points subdivided into two types, namely mines and mineral deposits. Mines can be dormant mines, continuously producing (active) mines, abandoned mines and intermittently producing mines. The mineral deposits can be exploited or unexploited. The dataset also contains information on mineralised fields (areas of high concentration of commodity) and mineralised provinces (broad areas where a given commodity occurs) as well as mineralised layers (veins of high concentration of commodity–linear feature).

Mines and deposits were buffered by 500 m and the mineralised layers by 1 000 m (less accurate).

The mining potential was determined based on the accuracy of the deposit mapping, its size and the type of commodities.

We considered four types of deposit mapping (arranged from high spatial accuracy to low):

- Mines and deposits (500 m radius).
- Mineralised layers (1 km buffer).
- Mineralised fields (high concentration of commodity).
- Mineralised provinces (broad area where commodity occurs).

The commodities were classified into two groups, namely economically important and other minerals. The minerals of economic importance (13) were obtained from the website of the Council for Geoscience. Table B1 lists the 13 minerals of economic importance in South Africa.

Table B1 Minerals of economic importance in South Africa.

Mineral	Symbol
Gold	Au
Platinum Group Metals	Pt
Diamonds (alluvial & kimberlite)	Da, Dk
Chromite	Cr
Manganese	Mn
Vanadium	V
Titanium	Ti
Zirconium	Zr
Antimony	Sb
Aluminum Silicates	Al
Coal	C
Fluorspar	F
Vermiculite	Vm

Table B2 illustrates how we classified mining potential into three categories: high, medium and low. We associated areas where an economically important commodity (such as gold) occurs in large deposits/mines, or where a mineralised field/layer of such commodity was mapped.

Table B2 Criteria used to map mining potential in South Africa.

Category	Type	Commodity
High	Large deposits/mines OR Mineralised fields/layers	Economically important
Medium	Medium mines OR Mineralised provinces	Economically important
	Large deposits/mines	Other
Low	Small deposits/mines OR Mineralised layers/fields/ provinces	Any

Table 17.1 Top vegetation types with high or medium mining potential in South Africa, ranked from the highest to the lowest potential. Percentage of the vegetation type area with high and medium mining potential is shown.

Vegetation types	% High	% Medium
Namib Seashore Vegetation	100	0
Richtersveld Coastal Duneveld	76	0
Northern Escarpment Dolomite Grassland	66	0
Subtropical Seashore Vegetation	53	0
Arid Estuarine Salt Marshes	49	0
Namaqualand Seashore Vegetation	0	0
Wakkerstroom Montane Grassland	0	90
Nwambyia-Pumbe Sandy Bushveld	0	84
Eastern Highveld Grassland	0	71
Springbokvlakte Thornveld	0	61
Soweto Highveld Grassland	0	60
Delagoa Lowveld	0	53

4. Degradation Vulnerability

4.1 Habitat Fragmentation

We considered three elements to derive the habitat fragmentation layer at landscape level. These were the surrounding land use (matrix resistance), the average fragment size and connectivity (distance between natural fragments). The first aspect is based on the assumption of different species movement to land cover types, by relating the species movements between different land use types to the resistance value. Landscape resistance thus represents the difficulty of a species to cross a certain land use type (Nikolakaki 2004). The approach is described in Box C. An overall habitat fragmentation index was derived by averaging the three aspects (Figure 17.2).

From this assessment, 244 vegetation types occur in areas with very low habitat fragmentation, 171 vegetation types in areas with low habitat fragmentation, 16 in areas with medium habitat fragmentation and two in areas with high habitat fragmentation. Highly fragmented vegetation types (last quartile of overall habitat fragmentation index) are listed in Table 17.2. The analysis of average fragment size separated vegetation types that are naturally fragmented (i.e. very small fragment size but high percentage extent) from those that have been fragmented due to anthropogenic change (i.e. very small fragment size and low percentage extent). For example, vegetation types such as Northern Afromontane Forest are naturally fragmented.

Table 17.2 Total number of highly fragmented vegetation types (11). Habitat fragmentation was quantified in terms of extent of habitat fragmentation (extent value), resistance to species movement (resistance value) and average fragment size (fragment size). The overall habitat fragmentation index ranged from 0 (not fragmented) to 85 (highly fragmented).

Vegetation types	Extent value	Resistance value	Fragment size	Overall index
Lourensford Alluvium Fynbos	91.0	82.7	80.5	84.8
Swartland Silcrete Renosterveld	96.7	57.0	72.7	75.5
Cape Lowland Alluvial Vegetation	90.4	43.4	57.5	63.8
Rûens Silcrete Renosterveld	93.9	40.8	56.4	63.7
Saldanha Granite Strandveld	85.0	45.9	56.9	62.6
Swartland Shale Renosterveld	85.0	43.2	57.4	61.9
Western Rûens Shale Renosterveld	82.0	44.0	59.3	61.7
Eastern Rûens Shale Renosterveld	82.0	43.9	58.9	61.6
Swartland Alluvium Renosterveld	79.0	46.2	57.6	60.9
Central Rûens Shale Renosterveld	84.0	42.1	56.3	60.8
Knysna Sand Fynbos	87.0	40.8	53.9	60.6

Box C: Habitat fragmentation.

1. Resistance Layer

The land cover map (including roads) was reclassified to reflect resistance to species movement. The types that allow minimal resistance were given a value of 0 (e.g. natural areas), while other types offer a greater resistance (Table C1). The layer was aggregated to 1 km distance in order to average the resistance value for fragments that are within the prescribed dispersal distance (1 km) using Grid Analyst in Arc View GIS. This produced a resistance layer with values ranging from 0 to 100. The cut-offs used for resistance values were as follows: 0–25, very low; 25–50, low; 50–75, medium; 75–100, high. We summarised the resistance values per vegetation type to classify vegetation types into four categories of habitat fragmentation in terms of resistance to species movement using equal interval categories.

Table C1 Land use classification based on the estimated landscape resistance value. Note: estimated resistance values were not species-specific.

Land use types	Landscape resistance value
Forests & Woodlands	0
Thicket & Bushland	0
Grassland	0
Wetlands	0
Waterbodies	25
Degraded land	50
Minor roads	50
Cultivated land	75
Forest plantation	75
Mines & Quarries	85
Major roads	85
Urban/Built-up Land	100

2. Extent of Habitat Transformation

To derive the extent of habitat transformation, we reclassified the NLC layer into natural and transformed areas (where natural areas = 0 and transformed areas = 1). The layer was then aggregated to 1 km using a sum method to calculate the percentage of habitat transformation within 1 km blocks. Values ranged from 0 (natural 1 × 1 km block) to 100 (transformed 1 × 1 km block). The layer was then summarised per vegetation type, which were reclassified into four categories of habitat fragmentation in terms of habitat transformation extent using equal interval categories.

3. Fragment Size

A unique value was assigned to each fragment of natural habitat per vegetation type (using the Arc Info command 'region group'). We then determined the area of each fragment of natural vegetation per vegetation type. The average fragment size was calculated for each vegetation type. We re-scaled the average fragment size value from 0 (average fragment size: 22 641 ha) to 100 (average fragment size: 1 ha). We reclassified vegetation types into four categories of habitat fragmentation in terms of fragment size using equal intervals.

4. Habitat Fragmentation Index

The overall habitat fragmentation index was derived per vegetation type. We averaged the values obtained for resistance to species movement, extent of habitat transformation and average fragment size. Vegetation types were then classified into four categories (very low, low, medium and high) of habitat fragmentation using equal intervals.

4.2 *Alien Plant Invasion*

We quantified alien plant invasion potential based on an assessment of the climatic correlates of distribution of 71 important invasive alien plants (Nel et al. 2004, Rouget et al. 2004). We assumed that alien plant species would have the potential to spread in areas identified as climatically suitable by a climatic envelope model (see Box D). Figure 17.3 illustrates the approach for three species. The index derived (re-scaled from 0 to 100) relates to the potential number of invader plants. This was then summarised per vegetation types and categorised into four categories.

A total of 157 of the vegetation types have low invasion potential where fewer than five species can invade, and five vegetation types have high invasion potential, being potentially suitable for more than 25 of the invader plants.

Box D: Mapping alien plant potential.

Climate Envelope Models (CEMs) are very useful at a broad scale to develop a general picture of where species are most likely to invade, especially in this region with marked climatic gradients. In this study, we used a variant of CEMs based on an oblique ellipse model, which calculates the Mahalanobis distance to the 'optimal' climate conditions. Such models are supported by the niche theory which assumes the existence of optimal environmental conditions for a species and that any deviation from this optimum is associated with a lower climatic suitability. These models are an improvement on traditional CEMs in that a continuous range of climatic suitability values can be equated with probability of occurrence. We derived climatic suitability surface for 71 major invader plants.

Preliminary analyses suggested that the relative importance of climatic factors was species-specific, making it difficult to identify a few 'generic' climatic variables that could be applied for all our species. We therefore reduced the large number of possible explanatory variables to three components (principal component axes 1, 2 and 3) using Principal Component Analysis (PCA). The first three components of the resulting PCA explained over 95% of the initial variation, based on the seven climatic variables with the greatest influence on plant species distribution. We then used these three climatic indices to derive the CEMs. We assumed that alien plant species would have the potential to spread in areas identified as climatically suitable by the CEMs. Rouget et al. (2004) describe the approach in more detail. Ideally, CEMs for alien plants should also be based on their bioclimatic occurrence in their continent of origin (Rutherford et al. 1995) and any other areas of the world where they are invasive.

Species potential distributions were derived on a grid of 1-minute resolution. We quantified alien plant invasion potential by calculating the number of alien plants that could potentially invade each 1-minute cell (i.e. for which the climate is suitable). The index was re-scaled from 0 to 100.

Most species are currently confined to 10% or less of the region, but could potentially invade up to 40%, based on their climatic envelope. Depending on the species, between 2% and 79% of the region is climatically suitable for species to invade, and some areas were suitable for up to 45 invader plants. Over one third of the major invader plants considered here have limited potential to substantially expand their distribution.

The number of potential invaders was then averaged per vegetation type to produce an index of alien plant invasion potential per vegetation type. This was classified into four categories (very low, low, medium and high) based on equal intervals.

5. Overall Vulnerability of Vegetation Types

Not all the vegetation types of the country are affected by land use pressures and degradation (Figure 17.4) in the same way. Out of 433 vegetation types, 207 vegetation types have a very low overall vulnerability index. A total of 217 vegetation types have a low overall vulnerability index. However, nine vegetation types have a medium overall vulnerability index (i.e. average greater than 50 for all vulnerability types).

The six vegetation types that are the most likely to be affected (based on the combined vulnerability index of land use and degradation) are (in decreasing order): Lourensford Alluvium Fynbos, Knysna Sand Fynbos, Algoa Sandstone Fynbos, Cape Flats Sand Fynbos, Egoli Granite Grassland and KwaZulu-Natal Sandstone Sourveld. Table 17.3 lists the three most threatened vegetation types for each land use and degradation pressure.

One can also analyse vulnerability in terms of the areas highly vulnerable to any land use or degradation pressure (score >75 for one or more of the six vulnerability types considered).

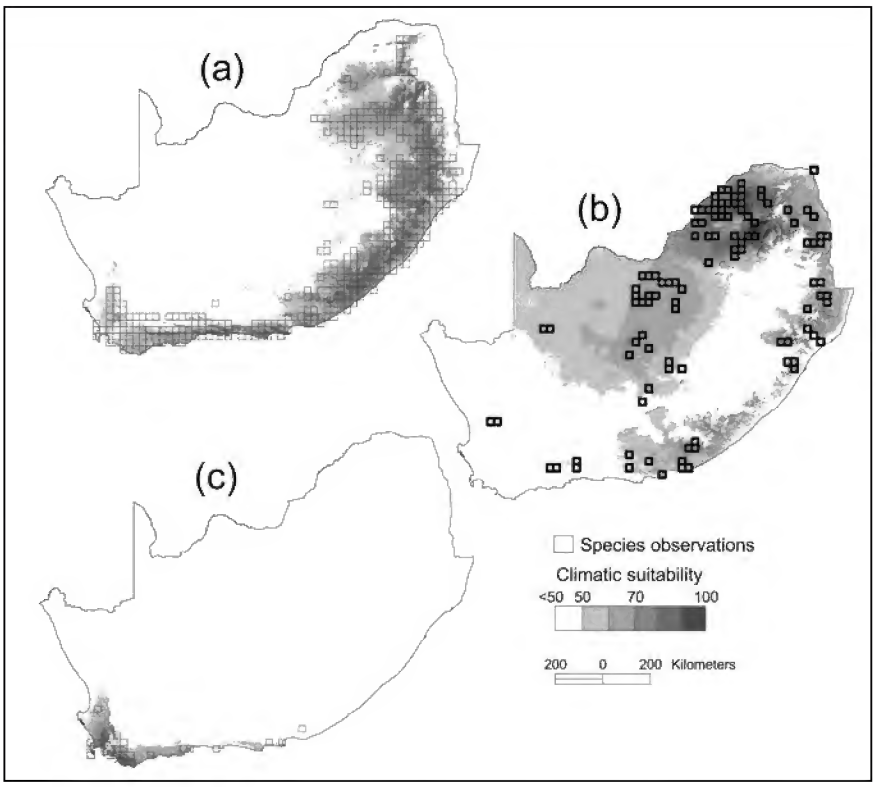

Figure 17.3 Species presence observations and climatic suitability derived from climatic envelope models for three characteristic species in South Africa, Lesotho and Swaziland: (a) *Acacia mearnsii*, a very widespread and abundant invader; (b) *Opuntia stricta*, a widespread and common invader; and (c) *Hakea drupacea*, a localised and abundant invader (from Rouget et al. 2004).

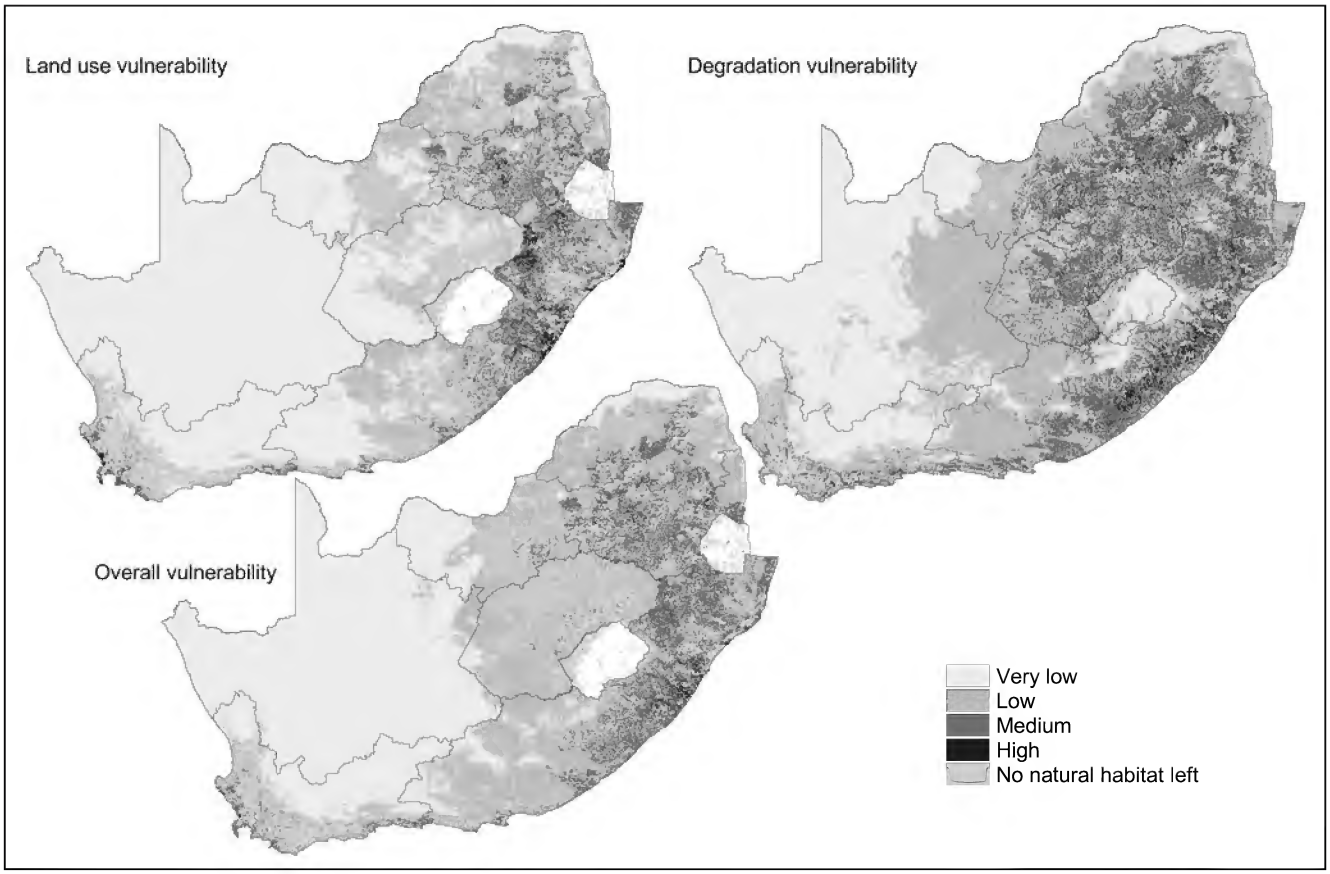

Figure 17.4 Average vulnerability of land use pressure, habitat degradation and overall vulnerability.

Table 17.3 Top three highly vulnerable vegetation types for both land use and degradation pressures as well as for overall vulnerability.

Vulnerability	Vegetation type 1	Vegetation type 2	Vegetation type 3
Land use	Mangrove Forest	Cape Flats Sand Fynbos	Cape Flats Dune Strandveld
Land degradation	Lourensford Alluvium Fynbos	Cape Lowland Alluvial Vegetation	Rûens Silcrete Renosterveld
Overall vulnerability	Lourensford Alluvium Fynbos	Knysna Sand Fynbos	Algoa Sandstone Fynbos

Regarding land use pressure only, the most threatened vegetation types (i.e. irrespective of the number of pressures) are in the Northern Cape coastal belt and localised parts of the interior of the province, central parts of Limpopo Province, parts of Gauteng, the coastal and mostly the southern parts of KwaZulu-Natal, the northeastern Eastern Cape and the lowlands of the Western Cape (Figure 17.5). In these terms, the most vulnerable vegetation types are the Cape Flats Sand Fynbos, Cape Flats Dune Strandveld, Lourensford Alluvium Fynbos, Peninsula Granite Fynbos, Peninsula Shale Renosterveld, Peninsula Sandstone Fynbos and Namib Seashore Vegetation (not identified as a vulnerable vegetation type based on the average overall vulnerability index).

Regarding degradation vulnerability only, Figure 17.6 highlights areas of high vulnerability to habitat fragmentation and/or alien plant invasion. This highlights 12 vegetation types most vulnerable to habitat degradation, including most of the Cape Lowlands vegetation types.

Predicting vulnerability to future land use pressures can be complex, but we found that the current extent of habitat transformation can serve as a broad predictor of vulnerability. The combined vulnerability index (see Figure 17.4) was correlated with the current extent of habitat transformation (Figure 17.7). For example, the Lourensford Alluvium Fynbos with 91% of its vegetation transformed has a high vulnerability index (vulnerability score of 61). However, there are many outliers where a vegetation type is either highly transformed with a low vulnerability index or vice versa. The land use vulnerability score was poorly correlated with the percentage of current habitat transformation.

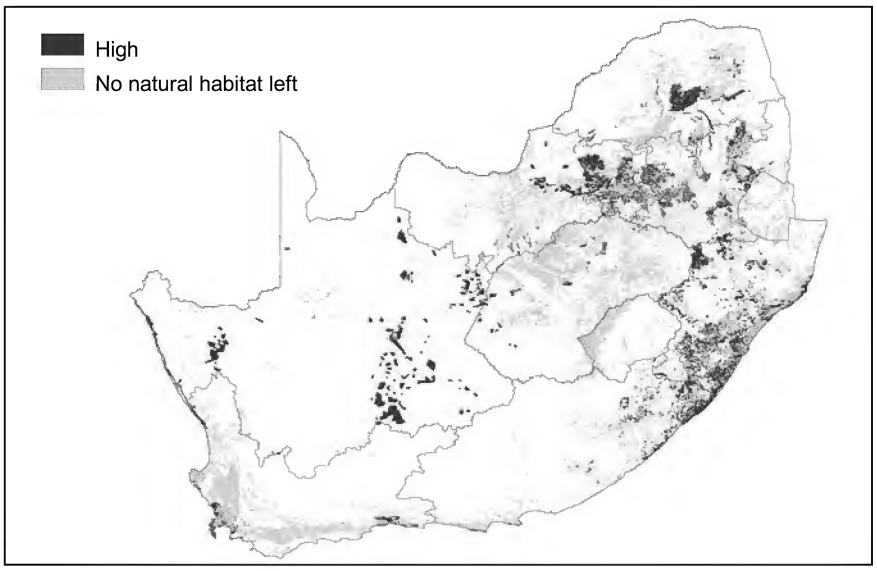

Figure 17.5 Areas of high future land use pressure based on land capability, afforestation, population growth and mining potential.

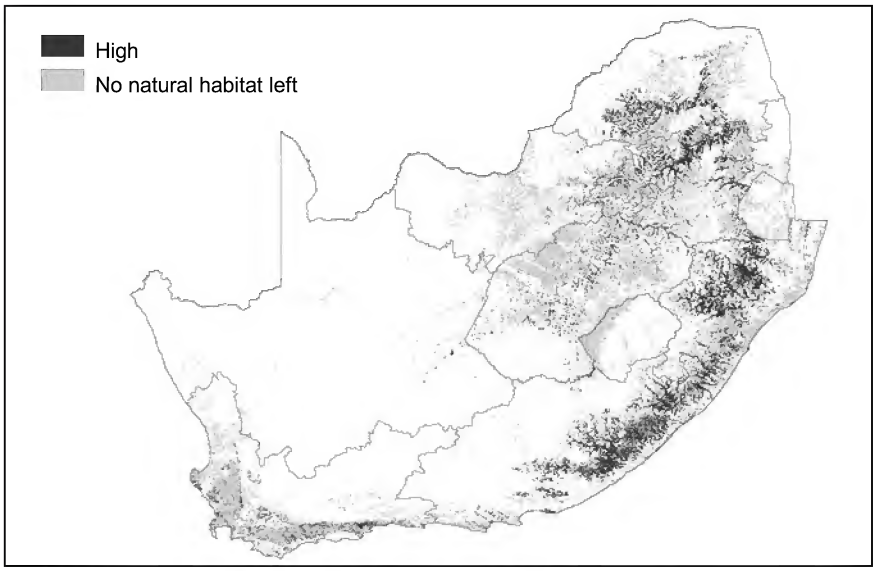

Figure 17.6 Areas of high degradation vulnerability to habitat fragmentation and alien plant invasion.

6. Conclusion

Recently, the National Spatial Biodiversity Assessment (Driver et al. 2005) quantified the current status of vegetation types. This revealed that 19 vegetation types are critically endangered, in other words ecosystem functioning has been severely disrupted by habitat transformation and such vegetation types could experience species loss. This also indicated that 53 vegetation types are endangered, 69 are vulnerable and 292 are least threatened.

Although the current ecosystem status highlights that 67% of the vegetation types are currently least threatened, our analysis of future vulnerability to land use pressures and degradation suggests that many vegetation types could experience further loss of habitat and/or loss of ecosystem functioning. The conservation challenge is now to identify which vegetation types should require immediate conservation efforts in order to mitigate the impacts of future land use changes. We recommend that vegetation types under high land use pressure but currently not transformed and/or not protected should receive conservation attention.

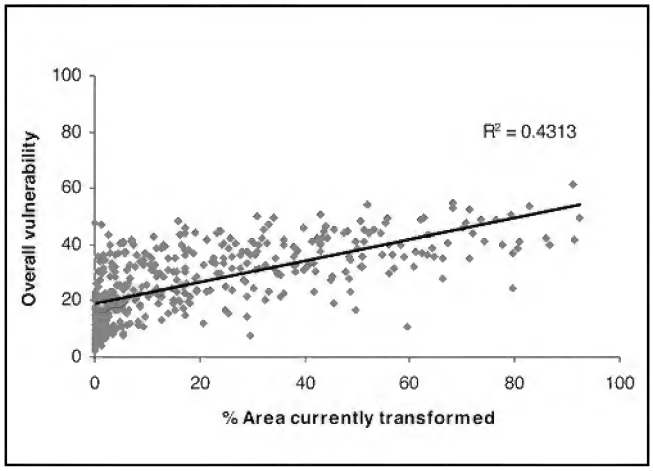

Figure 17.7 Relationship between the current habitat transformation and combined vulnerability (land use and degradation) in South Africa.

7. Credits

The unpublished version of the vegetation map used for this vulnerability analysis was provided by M.C. Rutherford and L. Mucina. The GIS data were obtained from L.W. Powrie. The layer of land capability, afforestation potential and population density was provided by B. Reyers and was requested from different sources. Z. Jonas and M. Rouget created the layer of mining potential and habitat fragmentation index. M. Rouget provided the layer of alien plant invasion. Z. Jonas, B. Mohamed and M. Rouget did the analysis. Z. Jonas was the lead author, M. Rouget and B. Reyers provided substantial input and editing on early drafts. L. Mucina and M.C. Rutherford provided final editorial comments. Valuable scientific and technical input was provided by conservation planners involved in the National Spatial Biodiversity Assessment.

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SALDANNA ofte SARDANJE BAY
Sardanje-Punt
Nota. de Sardanje-Bay is Veel Securder en Bequamer voor de Schepen als de Tafel-Bay: maer daar is gebreck van Soet water.
COSTA
Dit is de opdoening der Kusten
Dassen Hoeck
Dassen punt
Reypermonde
Hoek Stranden Langs
ROBBEN-EYLANDT
Daer de Slaven Inde Ketting Loopen
Klyne Leuw
Os montes claros em altura

K. Phillips

Vegetation Atlas of South Africa, Lesotho and Swaziland

18

Ladislav Mucina, Michael C. Rutherford and Leslie W. Powrie

with contributions by

Anthony G. Rebelo, Kelson G.T. Camp, Mervyn C. Lötter, David B. Hoare, Charles Boucher, George J. Bredenkamp, Jan H.J. Vlok, Doug I.W. Euston-Brown, Norbert Jürgens, P. Johann du Preez, Annelise le Roux, Ute Schmiedel, C. Robert Scott-Shaw, Noel van Rooyen, Linda Dobson, Anthony R. Palmer, Coert J. Geldenhuys, J. Wendy Lloyd †, Bertie van der Merwe, Hugo Bezuidenhout, Frances Siebert, Stefan J. Siebert, Peter S. Goodman, Pieter J.D. Winter, Nick Helme, Jacobus H.L. Smit, Philip G. Desmet, Michele Pfab, Bruce McKenzie, Robert J. Scholes, John C. Manning, Erich van Wyk, Nick Zambatis, Richard G. Lechmere-Oertel, Holger C. Eckhardt, J.-Wouter Lubbinge, Wayne S. Matthews, David J. McDonald, Walter J. Smit, Ronald G. Bennett, Zuziwe Jonas, Amanda T. Lombard, Willem de Frey, Riaan Robesson, Carl Oellermann, André Grobler, Adriaan van Niekerk, Johannes H. van der Merwe

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Introduction

The core of this book is the vegetation map of the region which is the culmination of many years of work by many people.

The vegetation units described become far more useful when they are made spatially explicit and the dimensions, distribution and shapes of each vegetation unit cannot adequately be described by text alone. Also the relationships between adjacent vegetation types as well as interdispersion patterns become clear through the device of the maps presented in this atlas.

The atlas is presented here as a systematic series of A4 maps. These depict 435 of the vegetation types of our subcontinental region. Not depicted in this edition is AZm 1 Cape Kelp Beds that is described in the text. The map of the vegetation types of the subantarctic Marion and Prince Edward Islands is to be found in Chapter 15. The mapping in this chapter corresponds closely to the large 1:1 000 000 map sheets of Mucina et al. (2005) and is also printed at this convenient scale. In this atlas a grey outline to polygons has been added to help differentiation between adjacent vegetation units. The A4 map pages include an area of overlap at the edges with the maps on overleaf pages and contain navigational arrows to adjacent sections of the map. The series of maps is preceded by an index map to page numbers of the maps of the atlas, followed by the legend to the vegetation types with colours and codes of the vegetation types. Given the large number of colours required for the atlas, the codes provide the definitive identity of vegetation types. For convenience this legend is reprinted as a separate booklet in a sleeve within the back cover of the book. Geographical names as approved by the South African Geographical Names Council are as gazetted before 1 January 2005.

A compact disc (CD) containing the electronic shape files of the map is placed in a sleeve within the front cover of the book. This CD also contains the software ArcReader suitable for viewing the map on computer. This is a particularly valuable and effective means of zooming in to view very small polygons and intricately divided vegetation types that are difficult to see on the printed maps. Some attributes are displayed when clicking on a polygon in the electronic map. These are Code used in the book, Name of the vegetation type, Conservation target, Percent of the vegetation type that is protected, Percent of the vegetation type that is unaltered, Conservation status and Protection status of the vegetation type, Area in square kilometres of the vegetation type, Area in square kilometres of the specific polygon, Code without space used on the map, Sort order (using numbers for biome, bioregion and vegetation type), Codes and names for biome, group and bioregion, and IDs for vegetation type, biome, group and bioregion used for linking data tables.

The maps of biomes and bioregions at much less detailed scales are to be found in Chapter 3.

Credits of work done are detailed in the individual major chapters (Chapters 4 to 14) and are therefore not repeated here.

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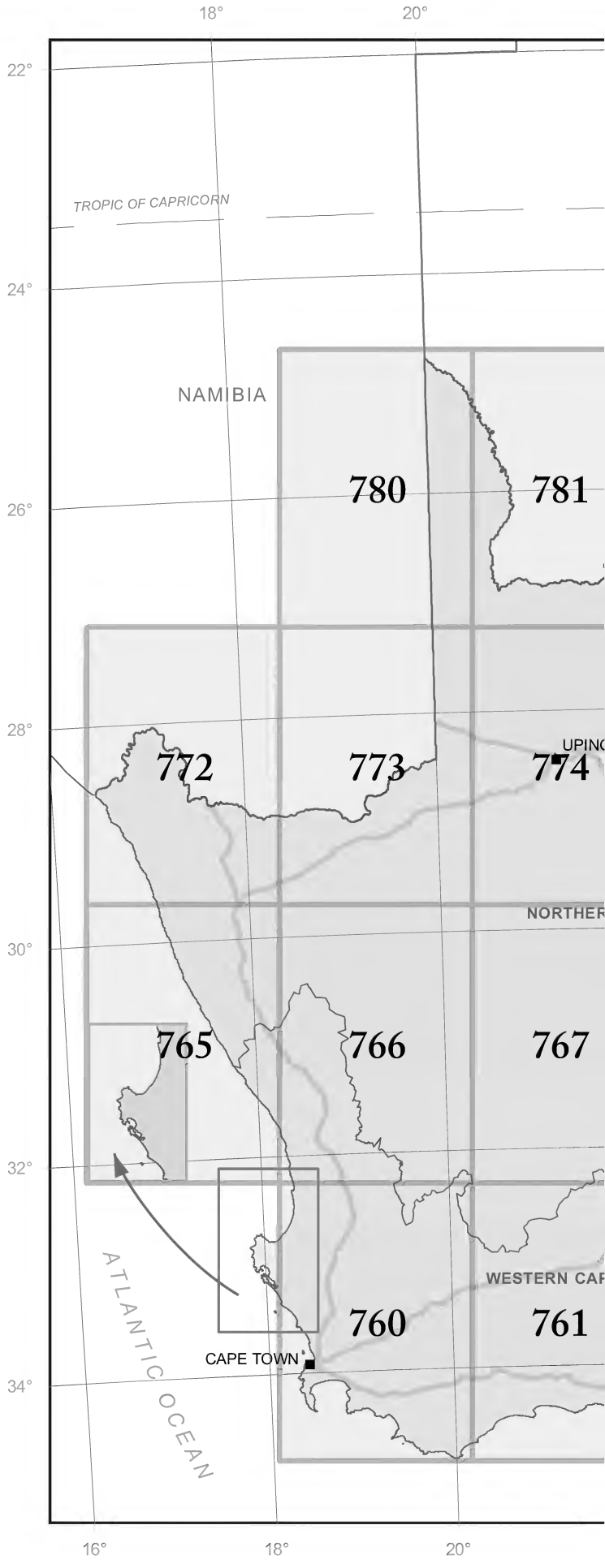

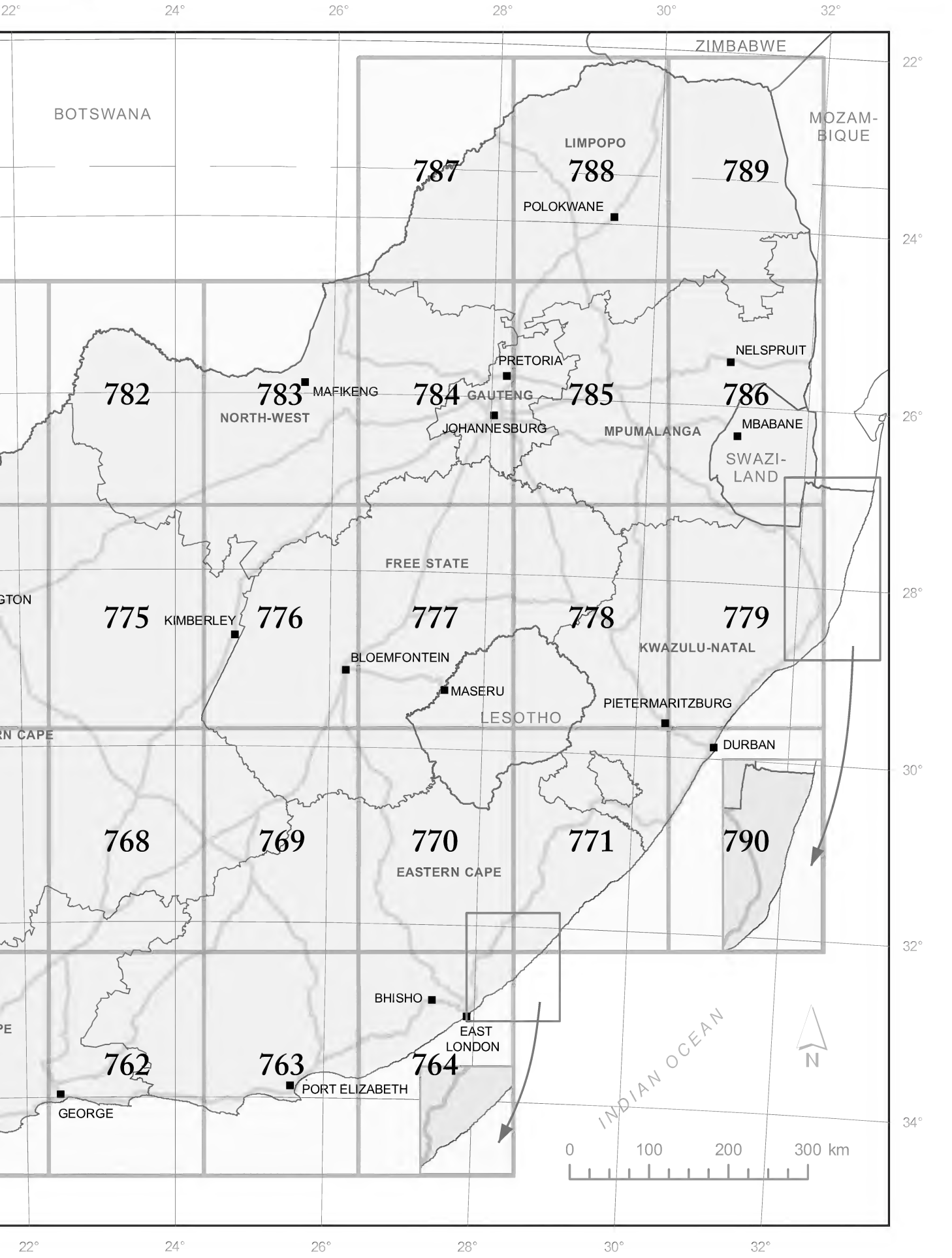
22°
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MOZAM-
BIQUE
LIMPOPO
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POLOKWANE
NELSPRUIT
PRETORIA
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783
MAFIKENG
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GAUTENG
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786
NORTH-WEST
JOHANNESBURG
MPUMALANGA
MBABANE
SWAZI-
LAND
FREE STATE
775
KIMBERLEY
776
777
778
779
KWAZULU-NATAL
BLOEMFONTEIN
MASERU
PIETERMARITZBURG
LESOTHO
DURBAN
768
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771
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EASTERN CAPE
BHISHO
EAST
LONDON
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764
PORT ELIZABETH
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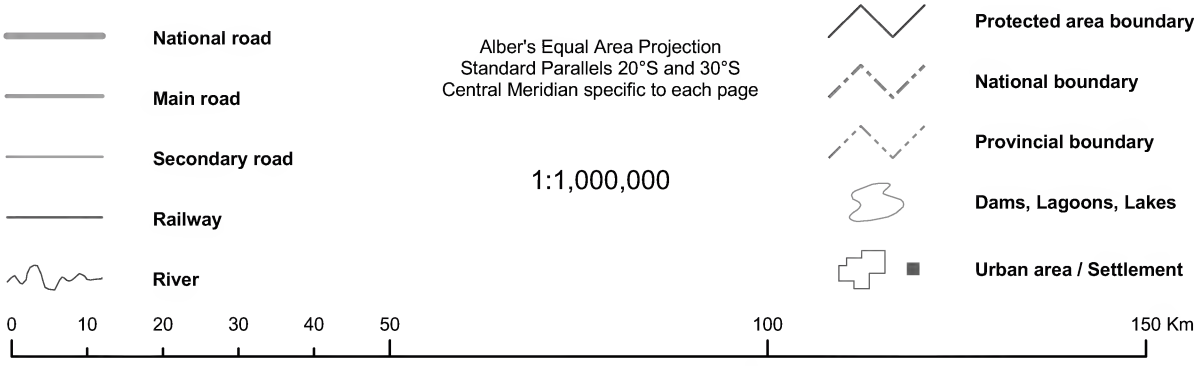
100
200
300 km

Legend to the Vegetation Units and Topographical Features



FYNBOS BIOME

Sandstone Fynbos

- FFs 1 Bokkeveld Sandstone Fynbos
- FFs 2 Graafwater Sandstone Fynbos
- FFs 3 Olifants Sandstone Fynbos
- FFs 4 Cederberg Sandstone Fynbos
- FFs 5 Winterhoek Sandstone Fynbos
- FFs 6 Piketberg Sandstone Fynbos
- FFs 7 North Hex Sandstone Fynbos
- FFs 8 South Hex Sandstone Fynbos
- FFs 9 Peninsula Sandstone Fynbos
- FFs 10 Hawequas Sandstone Fynbos
- FFs 11 Kogelberg Sandstone Fynbos
- FFs 12 Overberg Sandstone Fynbos
- FFs 13 North Sonderend Sandstone Fynbos
- FFs 14 South Sonderend Sandstone Fynbos
- FFs 15 North Langeberg Sandstone Fynbos
- FFs 16 South Langeberg Sandstone Fynbos
- FFs 17 Potberg Sandstone Fynbos
- FFs 18 North Outeniqua Sandstone Fynbos
- FFs 19 South Outeniqua Sandstone Fynbos
- FFs 20 Tsitsikamma Sandstone Fynbos
- FFs 21 North Rooiberg Sandstone Fynbos
- FFs 22 South Rooiberg Sandstone Fynbos
- FFs 23 North Swartberg Sandstone Fynbos
- FFs 24 South Swartberg Sandstone Fynbos
- FFs 25 North Kammanassie Sandstone Fynbos
- FFs 26 South Kammanassie Sandstone Fynbos
- FFs 27 Kouga Sandstone Fynbos
- FFs 28 Kouga Grassy Sandstone Fynbos
- FFs 29 Algoa Sandstone Fynbos
- FFs 30 Western Altimontane Sandstone Fynbos
- FFs 31 Swartberg Altimontane Sandstone Fynbos

Quartzite Fynbos

- FFq 1 Stinkfonteinberge Quartzite Fynbos
- FFq 2 Swartruggens Quartzite Fynbos
- FFq 3 Matjiesfontein Quartzite Fynbos
- FFq 4 Breede Quartzite Fynbos
- FFq 5 Grootrivier Quartzite Fynbos
- FFq 6 Suurberg Quartzite Fynbos

Sand Fynbos

- FFd 1 Namaqualand Sand Fynbos
- FFd 2 Leipoldtville Sand Fynbos
- FFd 3 Hopefield Sand Fynbos
- FFd 4 Atlantis Sand Fynbos

FFd 5 Cape Flats Sand Fynbos
FFd 6 Hangklip Sand Fynbos
FFd 7 Agulhas Sand Fynbos
FFd 8 Breede Sand Fynbos
FFd 9 Albertinia Sand Fynbos
FFd 10 Knysna Sand Fynbos
FFd 11 Southern Cape Dune Fynbos

Shale Fynbos

FFh 1 Kouebokkeveld Shale Fynbos
FFh 2 Matjiesfontein Shale Fynbos
FFh 3 Swartberg Shale Fynbos
FFh 4 Breede Shale Fynbos
FFh 5 Cape Winelands Shale Fynbos
FFh 6 Elgin Shale Fynbos
FFh 7 Greyton Shale Fynbos
FFh 8 Montagu Shale Fynbos
FFh 9 Garden Route Shale Fynbos
FFh 10 Suurberg Shale Fynbos

Shale Band Vegetation

FFb 1 Northern Inland Shale Band Vegetation
FFb 2 Western Coastal Shale Band Vegetation
FFb 3 Central Inland Shale Band Vegetation
FFb 4 Central Coastal Shale Band Vegetation
FFb 5 Eastern Inland Shale Band Vegetation
FFb 6 Eastern Coastal Shale Band Vegetation

Conglomerate Fynbos

FFt 1 Kango Conglomerate Fynbos
FFt 2 Loerie Conglomerate Fynbos

Alluvium Fynbos

FFa 1 Kouebokkeveld Alluvium Fynbos
FFa 2 Breede Alluvium Fynbos
FFa 3 Swartland Alluvium Fynbos
FFa 4 Lourensford Alluvium Fynbos

Granite Fynbos

FFg 1 Kamiesberg Granite Fynbos
FFg 2 Boland Granite Fynbos
FFg 3 Peninsula Granite Fynbos
FFg 4 Robertson Granite Fynbos
FFg 5 Garden Route Granite Fynbos

Silcrete Fynbos

FFc 1 Swellendam Silcrete Fynbos

Ferricrete Fynbos

FFf 1 Elim Ferricrete Fynbos
FFf 2 Potberg Ferricrete Fynbos

Limestone Fynbos

FFl 1 Agulhas Limestone Fynbos
FFl 2 De Hoop Limestone Fynbos
FFl 3 Canca Limestone Fynbos

Shale Renosterveld

FRs 1 Vanrhynsdorp Shale Renosterveld
FRs 2 Nieuwoudtville Shale Renosterveld
FRs 3 Roggeveld Shale Renosterveld
FRs 4 Ceres Shale Renosterveld
FRs 5 Central Mountain Shale Renosterveld
FRs 6 Matjiesfontein Shale Renosterveld
FRs 7 Montagu Shale Renosterveld
FRs 8 Breede Shale Renosterveld
FRs 9 Swartland Shale Renosterveld
FRs 10 Peninsula Shale Renosterveld
FRs 11 Western Rûens Shale Renosterveld
FRs 12 Central Rûens Shale Renosterveld
FRs 13 Eastern Rûens Shale Renosterveld
FRs 14 Mossel Bay Shale Renosterveld
FRs 15 Swartberg Shale Renosterveld

FRs 16 Uniondale Shale Renosterveld
FRs 17 Langkloof Shale Renosterveld
FRs 18 Baviaanskloof Shale Renosterveld
FRs 19 Humansdorp Shale Renosterveld

Granite Renosterveld

FRg 1 Namaqualand Granite Renosterveld
FRg 2 Swartland Granite Renosterveld
FRg 3 Robertson Granite Renosterveld

Dolerite Renosterveld

FRd 1 Nieuwoudtville-Roggeveld Dolerite Renosterveld
FRd 2 Hantam Plateau Dolerite Renosterveld

Alluvium Renosterveld

FRa 1 Breede Alluvium Renosterveld
FRa 2 Swartland Alluvium Renosterveld

Silcrete Renosterveld

FRc 1 Swartland Silcrete Renosterveld
FRc 2 Rûens Silcrete Renosterveld

Limestone Renosterveld

FRl 1 Kango Limestone Renosterveld

Western Strandveld

FS 1 Lambert's Bay Strandveld
FS 2 Saldanha Granite Strandveld
FS 3 Saldanha Flats Strandveld
FS 4 Saldanha Limestone Strandveld
FS 5 Langebaan Dune Strandveld
FS 6 Cape Flats Dune Strandveld
FS 7 Overberg Dune Strandveld
FS 8 Blombos Strandveld
FS 9 Groot Brak Dune Strandveld

SUCCULENT KAROO BIOME

Richtersveld Bioregion Bioregion

SKr 1 Central Richtersveld Mountain Shrubland
SKr 2 Upper Annisvlakte Succulent Shrubland
SKr 3 Goariep Mountain Succulent Shrubland
SKr 4 Lekkersing Succulent Shrubland
SKr 5 Vyftienmyl se Berge Succulent Shrubland
SKr 6 Stinkfonteinberge Eastern Apron Shrubland
SKr 7 Northern Richtersveld Scorpionstailveld
SKr 8 Rosyntjieberg Succulent Shrubland
SKr 9 Tatasberg Mountain Succulent Shrubland
SKr 10 Die Plate Succulent Shrubland
SKr 11 Rooiberg Quartz Vygieveld
SKr 12 Kosiesberg Succulent Shrubland
SKr 13 Southern Richtersveld Scorpionstailveld
SKr 14 Southern Richtersveld Inselberg Shrubland
SKr 15 Anenous Plateau Shrubland
SKr 16 Umdaus Mountains Succulent Shrubland
SKr 17 Eenriet Plains Succulent Shrubland
SKr 18 Bushmanland Inselberg Shrubland
SKr 19 Aggeneys Gravel Vygieveld

Namaqualand Hardeveld Bioregion

SKn 1 Namaqualand Klipkoppe Shrubland
SKn 2 Namaqualand Shale Shrubland
SKn 3 Namaqualand Blomveld
SKn 4 Namaqualand Heuweltjieveld
SKn 5 Platbakkies Succulent Shrubland
SKn 6 Kamiesberg Mountains Shrubland

Namaqualand Sandveld Bioregion

SKs 1 Richtersveld Coastal Duneveld
SKs 2 Northern Richtersveld Yellow Duneveld
SKs 3 Southern Richtersveld Yellow Duneveld
SKs 4 Richtersveld Sandy Coastal Scorpionstailveld
SKs 5 Richtersveld Red Duneveld

SKs 6 Oograbies Plains Sandy Grassland
SKs 7 Namaqualand Strandveld
SKs 8 Namaqualand Coastal Duneveld
SKs 9 Namaqualand Inland Duneveld
SKs 10 Riethuis-Wallekraal Quartz Vygieveld
SKs 11 Namaqualand Arid Grassland
SKs 12 Namaqualand Spinescent Grassland
SKs 13 Klawer Sandy Shrubland

Knersvlakte Bioregion

SKk 1 Northern Knersvlakte Vygieveld
SKk 2 Central Knersvlakte Vygieveld
SKk 3 Knersvlakte Quartz Vygieveld
SKk 4 Knersvlakte Shale Vygieveld
SKk 5 Vanrhynsdorp Gannabosveld
SKk 6 Knersvlakte Dolomite Vygieveld
SKk 7 Citrusdal Vygieveld
SKk 8 Piketberg Quartz Succulent Shrubland

Trans-Escarpment Succulent Karoo Bioregion

SKt 1 Western Bushmanland Klipveld
SKt 2 Hantam Karoo
SKt 3 Roggeveld Karoo

Rainshadow Valley Karoo Bioregion

SKv 1 Doringrivier Quartzite Karoo
SKv 2 Swartruggens Quartzite Karoo
SKv 3 Agter-Sederberg Shrubland
SKv 4 Tanqua Escarpment Shrubland
SKv 5 Tanqua Karoo
SKv 6 Koedoesberge-Moordenaars Karoo
SKv 7 Robertson Karoo
SKv 8 Western Little Karoo
SKv 9 Western Gwarrieveld
SKv 10 Little Karoo Quartz Vygieveld
SKv 11 Eastern Little Karoo
SKv 12 Willowmore Gwarrieveld
SKv 13 Prince Albert Succulent Karoo
SKv 14 Steytlerville Karoo

DESERT BIOME

Namib Desert Bioregion

Dn 1 Alexander Bay Coastal Duneveld
Dn 2 Namib Lichen Fields
Dn 3 Western Gariep Plains Desert
Dn 4 Western Gariep Lowland Desert
Dn 5 Western Gariep Hills Desert

Gariep Desert Bioregion

Dg 1 Noms Mountain Desert
Dg 2 Richtersberg Mountain Desert
Dg 3 Richtersveld Sheet Wash Desert
Dg 4 Kwaggarug Mountain Desert
Dg 5 Kahams Mountain Desert
Dg 6 Helskloof Canyon Desert
Dg 7 Northern Nababiepsberge Mountain Desert
Dg 8 Southern Nababiepsberge Mountain Desert
Dg 9 Eastern Gariep Plains Desert
Dg 10 Eastern Gariep Rocky Desert

NAMA-KAROO BIOME

Bushmanland Bioregion

NKb 1 Lower Gariep Broken Veld
NKb 2 Blouputs Karroid Thornveld
NKb 3 Bushmanland Arid Grassland
NKb 4 Bushmanland Sandy Grassland
NKb 5 Kalahari Karroid Shrubland
NKb 6 Bushmanland Basin Shrubland

Upper Karoo Bioregion

- NKu 1 Western Upper Karoo
- NKu 2 Upper Karoo Hardeveld
- NKu 3 Northern Upper Karoo
- NKu 4 Eastern Upper Karoo

Lower Karoo Bioregion

- NKl 1 Gamka Karoo
- NKl 2 Eastern Lower Karoo
- NKl 3 Lower Karoo Gwarrieveld
- NKl 4 Albany Broken Veld

GRASSLAND BIOME

Drakensberg Grassland Bioregion

- Gd 1 Amathole Montane Grassland
- Gd 2 Amathole Mistbelt Grassland
- Gd 3 Stormberg Plateau Grassland
- Gd 4 Southern Drakensberg Highland Grassland
- Gd 5 Northern Drakensberg Highland Grassland
- Gd 6 Drakensberg-Amathole Afromontane Fynbos
- Gd 7 uKhahlamba Basalt Grassland
- Gd 8 Lesotho Highland Basalt Grassland
- Gd 9 Western Lesotho Basalt Shrubland
- Gd 10 Drakensberg Afroalpine Heathland

Dry Highveld Grassland Bioregion

- Gh 1 Karoo Escarpment Grassland
- Gh 2 Aliwal North Dry Grassland
- Gh 3 Xhariep Karroid Grassland
- Gh 4 Besemkaree Koppies Shrubland
- Gh 5 Bloemfontein Dry Grassland
- Gh 6 Central Free State Grassland
- Gh 7 Winburg Grassy Shrubland
- Gh 8 Bloemfontein Karroid Shrubland
- Gh 9 Western Free State Clay Grassland
- Gh 10 Vaal-Vet Sandy Grassland
- Gh 11 Vredefort Dome Granite Grassland
- Gh 12 Vaal Reefs Dolomite Sinkhole Woodland
- Gh 13 Klerksdorp Thornveld
- Gh 14 Western Highveld Sandy Grassland
- Gh 15 Carletonville Dolomite Grassland

Mesic Highveld Grassland Bioregion

- Gm 1 Zastron Moist Grassland
- Gm 2 Senqu Montane Shrubland
- Gm 3 Eastern Free State Clay Grassland
- Gm 4 Eastern Free State Sandy Grassland
- Gm 5 Basotho Montane Shrubland
- Gm 6 Frankfort Highveld Grassland
- Gm 7 Northern Free State Shrubland
- Gm 8 Soweto Highveld Grassland
- Gm 9 Tsakane Clay Grassland
- Gm 10 Egoli Granite Grassland
- Gm 11 Rand Highveld Grassland
- Gm 12 Eastern Highveld Grassland
- Gm 13 Amersfoort Highveld Clay Grassland
- Gm 14 Wakkerstroom Montane Grassland
- Gm 15 Paulpietersburg Moist Grassland
- Gm 16 KaNgwane Montane Grassland
- Gm 17 Barberton Montane Grassland
- Gm 18 Lydenburg Montane Grassland
- Gm 19 Sekhukhune Montane Grassland
- Gm 20 Leolo Summit Sourveld
- Gm 21 Lydenburg Thornveld
- Gm 22 Northern Escarpment Dolomite Grassland
- Gm 23 Northern Escarpment Quartzite Sourveld
- Gm 24 Northern Escarpment Afromontane Fynbos
- Gm 25 Woodbush Granite Grassland
- Gm 26 Wolkberg Dolomite Grassland
- Gm 27 Strydpoort Summit Sourveld
- Gm 28 Soutpansberg Summit Sourveld
- Gm 29 Waterberg-Magaliesberg Summit Sourveld

Sub-Escarpment Grassland Bioregion

- Gs 1 Northern Zululand Mistbelt Grassland
- Gs 2 Ithala Quartzite Sourveld
- Gs 3 Low Escarpment Moist Grassland
- Gs 4 Northern KwaZulu-Natal Moist Grassland
- Gs 5 Northern KwaZulu-Natal Shrubland
- Gs 6 KwaZulu-Natal Highland Thornveld
- Gs 7 Income Sandy Grassland
- Gs 8 Mooi River Highland Grassland
- Gs 9 Midlands Mistbelt Grassland
- Gs 10 Drakensberg Foothill Moist Grassland
- Gs 11 Southern KwaZulu-Natal Moist Grassland
- Gs 12 East Griqualand Grassland
- Gs 13 Mabela Sandy Grassland
- Gs 14 Mthatha Moist Grassland
- Gs 15 Tsomo Grassland
- Gs 16 Queenstown Thornveld
- Gs 17 Tarkastad Montane Shrubland
- Gs 18 Bedford Dry Grassland

SAVANNA BIOME

Central Bushveld Bioregion

- SVcb 1 Dwaalboom Thornveld
- SVcb 2 Madikwe Dolomite Bushveld
- SVcb 3 Zeerust Thornveld
- SVcb 4 Dwarsberg-Swartruggens Mountain Bushveld
- SVcb 5 Pilanesberg Mountain Bushveld
- SVcb 6 Marikana Thornveld
- SVcb 7 Norite Koppies Bushveld
- SVcb 8 Moot Plains Bushveld
- SVcb 9 Gold Reef Mountain Bushveld
- SVcb 10 Gauteng Shale Mountain Bushveld
- SVcb 11 Andesite Mountain Bushveld
- SVcb 12 Central Sandy Bushveld
- SVcb 13 Loskop Mountain Bushveld
- SVcb 14 Loskop Thornveld
- SVcb 15 Springbokvlakte Thornveld
- SVcb 16 Western Sandy Bushveld
- SVcb 17 Waterberg Mountain Bushveld
- SVcb 18 Roodeberg Bushveld
- SVcb 19 Limpopo Sweet Bushveld
- SVcb 20 Makhado Sweet Bushveld
- SVcb 21 Soutpansberg Mountain Bushveld
- SVcb 22 VhaVenda Miombo
- SVcb 23 Polokwane Plateau Bushveld
- SVcb 24 Mamabolo Mountain Bushveld
- SVcb 25 Poung Dolomite Mountain Bushveld
- SVcb 26 Ohrigstad Mountain Bushveld
- SVcb 27 Sekhukhune Plains Bushveld
- SVcb 28 Sekhukhune Mountain Bushveld

Mopane Bioregion

- SVmp 1 Musina Mopane Bushveld
- SVmp 2 Limpopo Ridge Bushveld
- SVmp 3 Cathedral Mopane Bushveld
- SVmp 4 Mopane Basalt Shrubland
- SVmp 5 Tsende Mopaneveld
- SVmp 6 Lowveld Rugged Mopaneveld
- SVmp 7 Phalaborwa-Timbavati Mopaneveld
- SVmp 8 Mopane Gabbro Shrubland

Lowveld Bioregion

- SVl 1 Makuleke Sandy Bushveld
- SVl 2 Nwambyia-Pumbe Sandy Bushveld
- SVl 3 Granite Lowveld
- SVl 4 Delagoa Lowveld
- SVl 5 Tshokwane-Hlane Basalt Lowveld
- SVl 6 Gabbro Grassy Bushveld
- SVl 7 Gravelotte Rocky Bushveld
- SVl 8 Tzaneen Sour Bushveld
- SVl 9 Legogote Sour Bushveld
- SVl 10 Pretoriuskop Sour Bushveld

SVl 11 Malelane Mountain Bushveld
SVl 12 Kaalrug Mountain Bushveld
SVl 13 Barberton Serpentine Sourveld
SVl 14 Swaziland Sour Bushveld
SVl 15 Northern Lebombo Bushveld
SVl 16 Southern Lebombo Bushveld
SVl 17 Lebombo Summit Sourveld
SVl 18 Tembe Sandy Bushveld
SVl 19 Western Maputaland Sandy Bushveld
SVl 20 Western Maputaland Clay Bushveld
SVl 21 Makatini Clay Thicket
SVl 22 Northern Zululand Sourveld
SVl 23 Zululand Lowveld
SVl 24 Zululand Coastal Thornveld

Sub-Escarpment Savanna Bioregion

SVs 1 Thukela Valley Bushveld
SVs 2 Thukela Thornveld
SVs 3 KwaZulu-Natal Hinterland Thornveld
SVs 4 Ngongoni Veld
SVs 5 KwaZulu-Natal Sandstone Sourveld
SVs 6 Eastern Valley Bushveld
SVs 7 Bhisho Thornveld

Eastern Kalahari Bushveld Bioregion

SVk 1 Mafikeng Bushveld
SVk 2 Stella Bushveld
SVk 3 Schweizer-Reneke Bushveld
SVk 4 Kimberley Thornveld
SVk 5 Vaalbos Rocky Shrubland
SVk 6 Schmidtsdrif Thornveld
SVk 7 Ghaap Plateau Vaalbosveld
SVk 8 Kuruman Vaalbosveld
SVk 9 Kuruman Thornveld
SVk 10 Kuruman Mountain Bushveld
SVk 11 Molopo Bushveld
SVk 12 Kathu Bushveld
SVk 13 Olifantshoek Plains Thornveld
SVk 14 Postmasburg Thornveld
SVk 15 Koranna-Langeberg Mountain Bushveld
SVk 16 Gordonia Plains Shrubland

Kalahari Duneveld Bioregion

SVkd 1 Gordonia Duneveld
SVkd 2 Gordonia Kameeldoring Bushveld
SVkd 3 Auob Duneveld
SVkd 4 Nossob Bushveld

ALBANY THICKET BIOME

AT 1 Southern Cape Valley Thicket
AT 2 Gamka Thicket
AT 3 Groot Thicket
AT 4 Gamtoos Thicket
AT 5 Sundays Noorsveld
AT 6 Sundays Thicket
AT 7 Coega Bontveld
AT 8 Kowie Thicket
AT 9 Albany Coastal Belt
AT 10 Great Fish Noorsveld
AT 11 Great Fish Thicket
AT 12 Buffels Thicket
AT 13 Eastern Cape Escarpment Thicket
AT 14 Camdebo Escarpment Thicket

INDIAN OCEAN COASTAL BELT

CB 1 Maputaland Coastal Belt
CB 2 Maputaland Wooded Grassland
CB 3 KwaZulu-Natal Coastal Belt
CB 4 Pondoland-Ugu Sandstone Coastal Sourveld
CB 5 Transkei Coastal Belt

FORESTS

Zonal & Intrazonal Forests

FOz 1 Southern Afrotemperate Forest
FOz 2 Northern Afrotemperate Forest
FOz 3 Southern Mistbelt Forest
FOz 4 Northern Mistbelt Forest
FOz 5 Scarp Forest
FOz 6 Southern Coastal Forest
FOz 7 Northern Coastal Forest
FOz 8 Sand Forest
FOz 9 Ironwood Dry Forest

Azonal Forests

FOa 1 Lowveld Riverine Forest
FOa 2 Swamp Forest
FOa 3 Mangrove Forest

AZONAL VEGETATION

Estuarine Vegetation

AZe 1 Arid Estuarine Salt Marshes
AZe 2 Cape Estuarine Salt Marshes
AZe 3 Subtropical Estuarine Salt Marshes

Seashore Vegetation

AZd 1 Namib Seashore Vegetation
AZd 2 Namaqualand Seashore Vegetation
AZd 3 Cape Seashore Vegetation
AZd 4 Subtropical Seashore Vegetation

Eastern Strandveld

AZs 1 Algoa Dune Strandveld
AZs 2 Albany Dune Strandveld
AZs 3 Subtropical Dune Thicket

Alluvial Vegetation

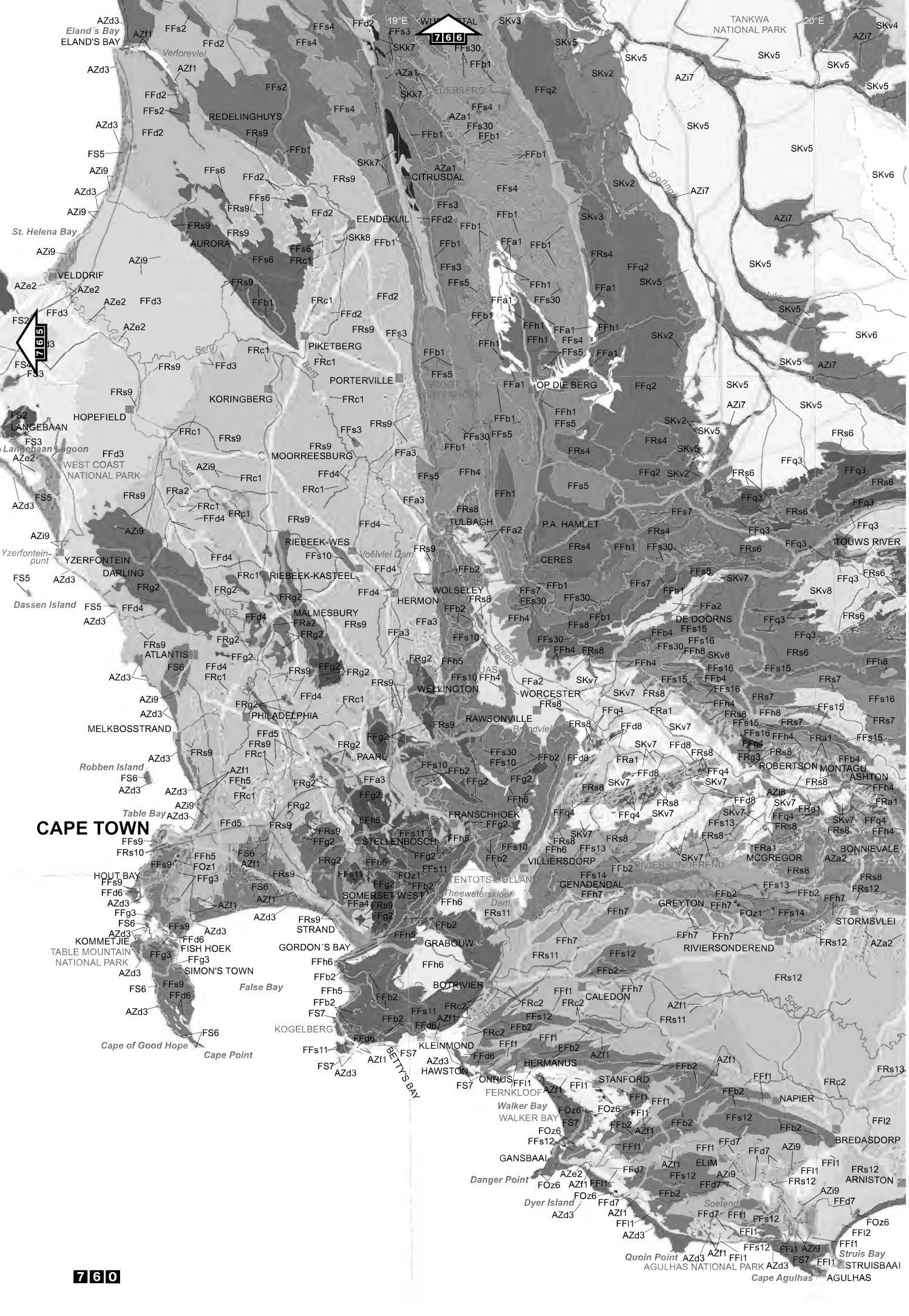
AZa 1 Fynbos Riparian Vegetation
AZa 2 Cape Lowland Alluvial Vegetation
AZa 3 Lower Gariep Alluvial Vegetation
AZa 4 Upper Gariep Alluvial Vegetation
AZa 5 Highveld Alluvial Vegetation
AZa 6 Albany Alluvial Vegetation
AZa 7 Subtropical Alluvial Vegetation

Freshwater Wetlands

AZf 1 Cape Lowland Freshwater Wetlands
AZf 2 Cape Vernal Pools
AZf 3 Eastern Temperate Freshwater Wetlands
AZf 4 Drakensberg Wetlands
AZf 5 Lesotho Mires
AZf 6 Subtropical Freshwater Wetlands

Inland Saline Vegetation

AZi 1 Namaqualand Riviere
AZi 2 Namaqualand Salt Pans
AZi 3 Southern Kalahari Mekgacha
AZi 4 Southern Kalahari Salt Pans
AZi 5 Bushmanland Vloere
AZi 6 Southern Karoo Riviere
AZi 7 Tanqua Wash Riviere
AZi 8 Muscadel Riviere
AZi 9 Cape Inland Salt Pans
AZi 10 Highveld Salt Pans
AZi 11 Subtropical Salt Pans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Eland´s Bay
Verlorevlei
REDELINGHUYS
CITRUSDAL
EENDEKUIL
AURORA
VELDDRIF
St. Helena Bay
PIKETBERG
PORTERVILLE
OP DIE BERG
KORINGBERG
HOPEFIELD
LANGEBAAN
Langebaan Lagoon
WEST COAST NATIONAL PARK
MOORREESBURG
TULBAGH
P.A. HAMLET
RIEBEEK-WES
RIEBEEK-KASTEEL
YZERFONTEIN
Yzerfontein-punt
DARLING
CERES
TOUWS RIVER
Voëlvlei Dam
WOLSELEY
HERMON
MALMESBURY
DE DOORNS
Dassen Island
ATLANTIS
WELLINGTON
WORCESTER
PHILADELPHIA
RAWSONVILLE
MELKBOSSTRAND
Robben Island
PAARL
ROBERTSON
MONTAGU
ASHTON
Table Bay
FRANSCHHOEK
STELLENBOSCH
VILLIERSDORP
MCGREGOR
BONNIEVALE
HOUT BAY
TENTOTS-HOLLAND
GENADENDAL
RIVIERSONDEREND
SOMERSET WEST
Theewaterskloof Dam
GREYTON
STORMSVLEI
STRAND
KOMMETJIE
GORDON´S BAY
GRABOUW
TABLE MOUNTAIN NATIONAL PARK
FISH HOEK
SIMON'S TOWN
False Bay
BOTRIVIER
CALEDON
KOGELBERG
Cape of Good Hope
Cape Point
KLEINMOND
HERMANUS
HAWSTON
ONRUS
FERNKLOOF
BETTY'S BAY
STANFORD
NAPIER
Walker Bay
WALKER BAY
BREDASDORP
GANSBAAI
ELIM
ARNISTON
Danger Point
Dyer Island
Quoin Point
AGULHAS NATIONAL PARK
Cape Agulhas
AGULHAS
Struis Bay
STRUISBAAI
TANKWA NATIONAL PARK
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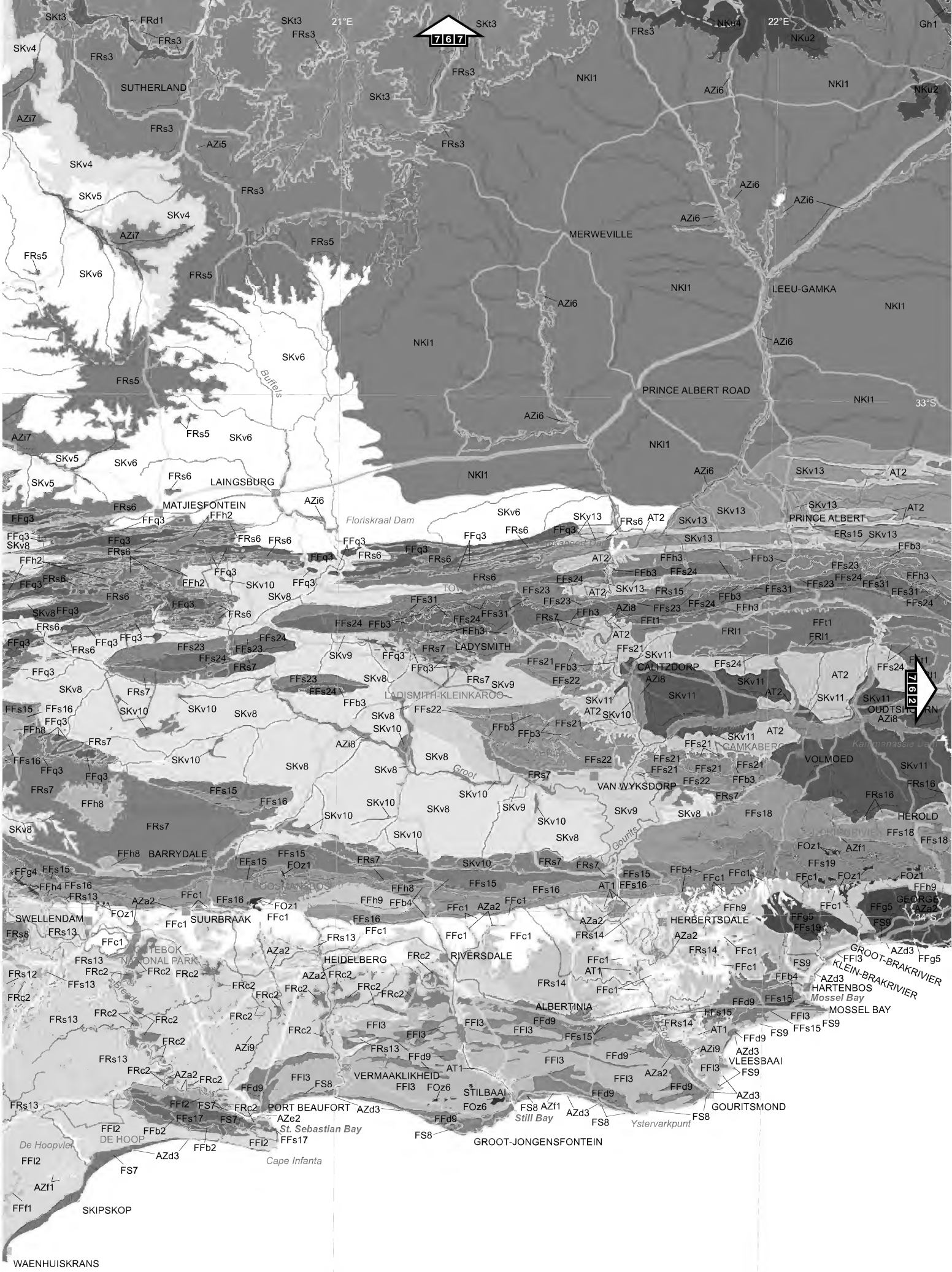
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LAINGSBURG
MATJIESFONTEIN
LADYSMITH
LADISMITH-KLEINKAROO
CALITZDORP
GAMKABERG
VOLMOED
VAN WYKSDORP
HERBERTSDALE
HEROLD
BARRYDALE
SUURBRAAK
SWELLENDAM
RIVERSDALE
HEIDELBERG
ALBERTINIA
VERMAAKLIKHEID
STILBAAI
PORT BEAUFORT
GROOT-JONGENSFONTEIN
GOURITSMOND
VLEESBAAI
MOSSEL BAY
HARTENBOS
GROOT-BRAKRIVIER
KLEIN-BRAKRIVIER
OUDTSHOORN
DE HOOP
SKIPSKOP
WAENHUISKRANS
Floriskraal Dam
Buffels
Groot
Gourits
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Still Bay
St. Sebastian Bay
Cape Infanta
Ystervarkpunt
De Hoopvlei
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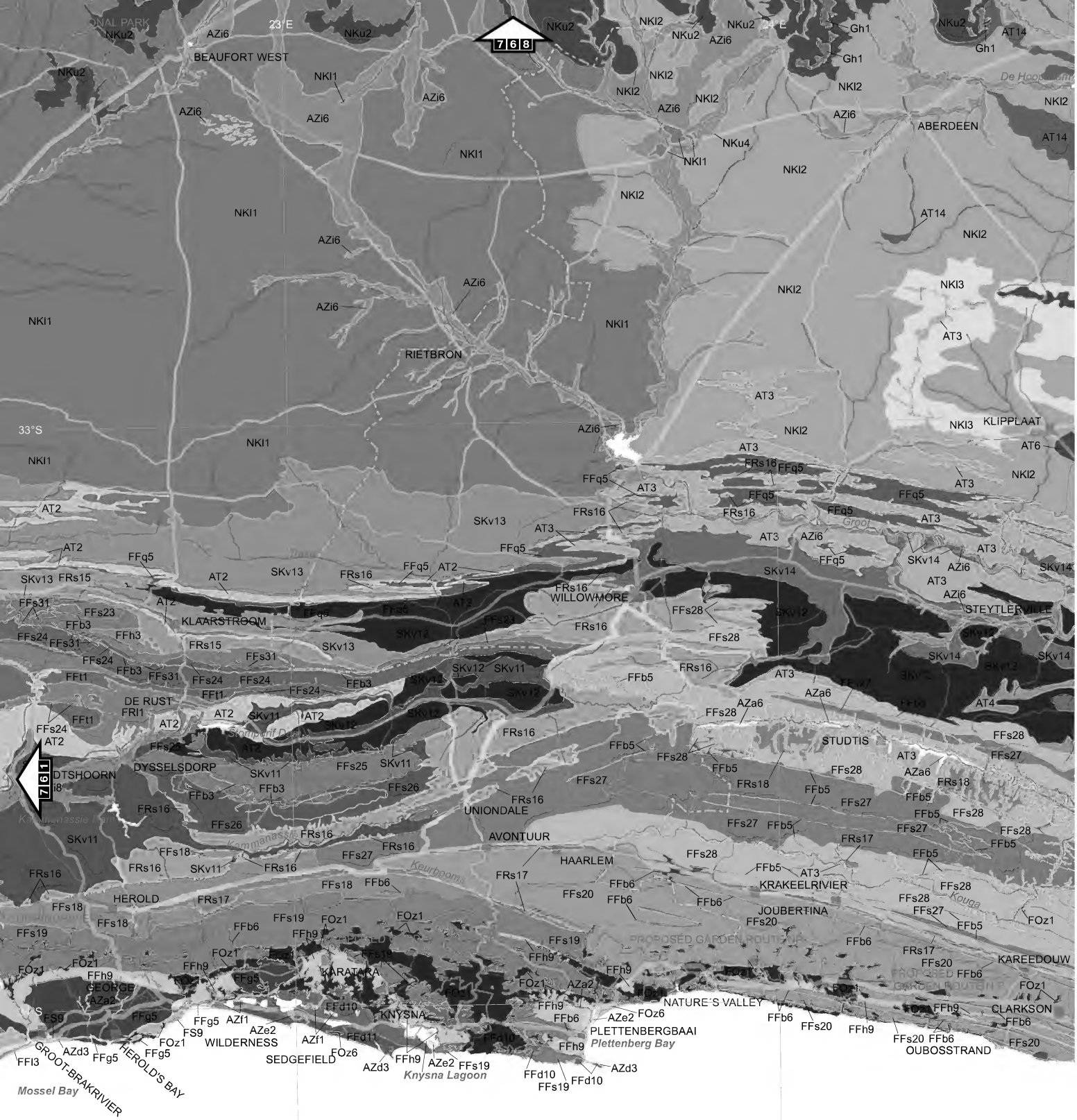

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ABERDEEN
KLIPPLAAT
WILLOWMORE
KLAARSTROOM
STEYTLERVILLE
DE RUST
DYSSELSDORP
STUDTIS
UNIONDALE
AVONTUUR
HAARLEM
KRAKEELRIVIER
JOUBERTINA
HEROLD
KARATARA
KNYSNA
NATURE'S VALLEY
KAREEDOUW
CLARKSON
OUBOSSTRAND
PLETTENBERGBAAI
Plettenberg Bay
Knysna Lagoon
WILDERNESS
SEDGEFIELD
GEORGE
HEROLD'S BAY
GROOT-BRAKRIVIER
Mossel Bay
PROPOSED GARDEN ROUTE
Kouga
Keurbooms
Kammanassie
Grootvlei
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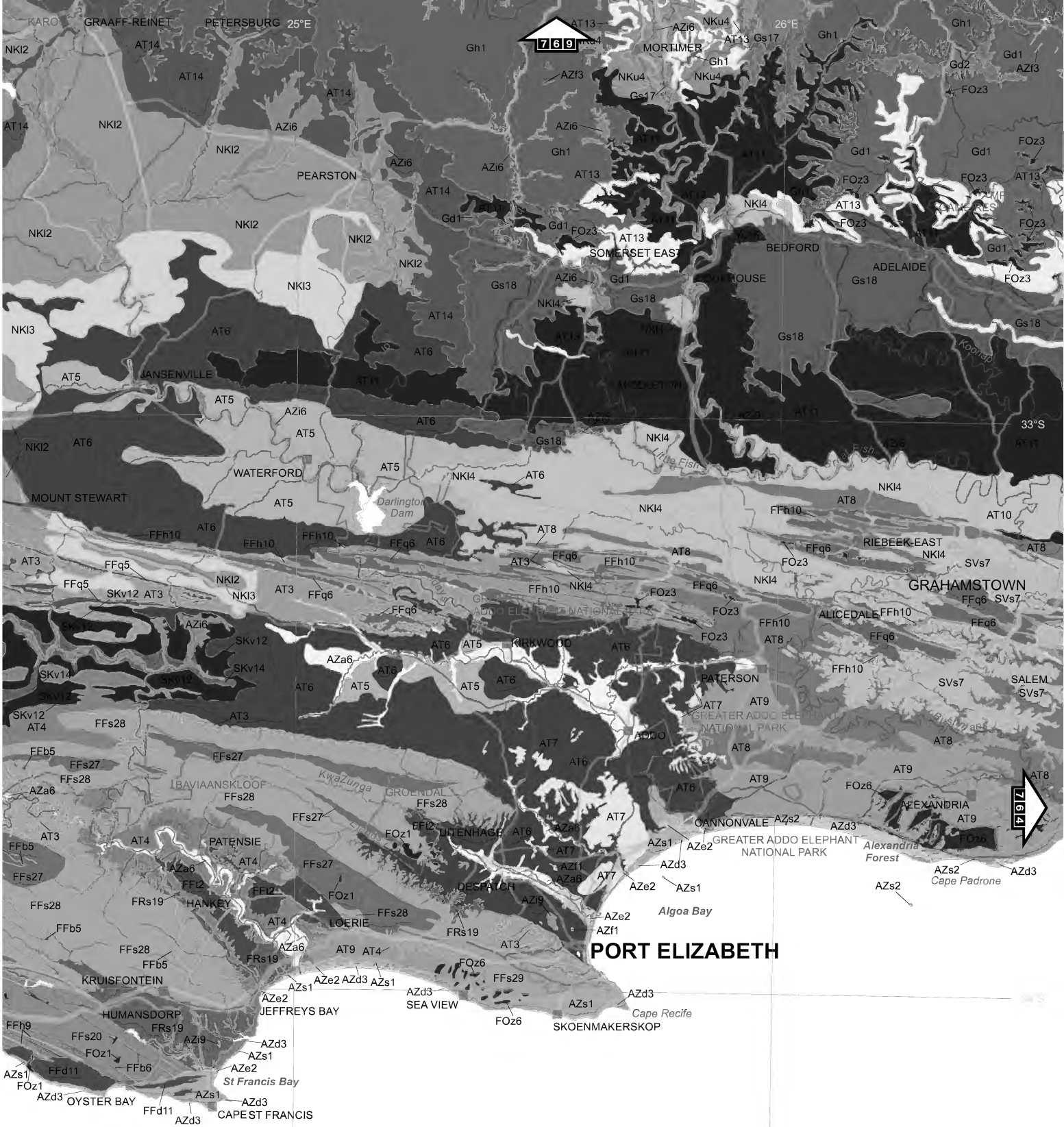
33°S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GRAAFF-REINET
PETERSBURG
MORTIMER
PEARSTON
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BEDFORD
ADELAIDE
JANSENVILLE
WATERFORD
MOUNT STEWART
Darlington Dam
RIEBEEK-EAST
GRAHAMSTOWN
ALICEDALE
KIRKWOOD
PATERSON
SALEM
GREATER ADDO ELEPHANT NATIONAL PARK
BAVIAANSKLOOF
GROENDAL
PATENSIE
UITENHAGE
CANNONVALE
ALEXANDRIA
Alexandria Forest
Cape Padrone
DESPATCH
HANKEY
LOERIE
Algoa Bay
PORT ELIZABETH
KRUISFONTEIN
JEFFREYS BAY
HUMANSDORP
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Cape Recife
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St Francis Bay
OYSTER BAY
CAPE ST FRANCIS
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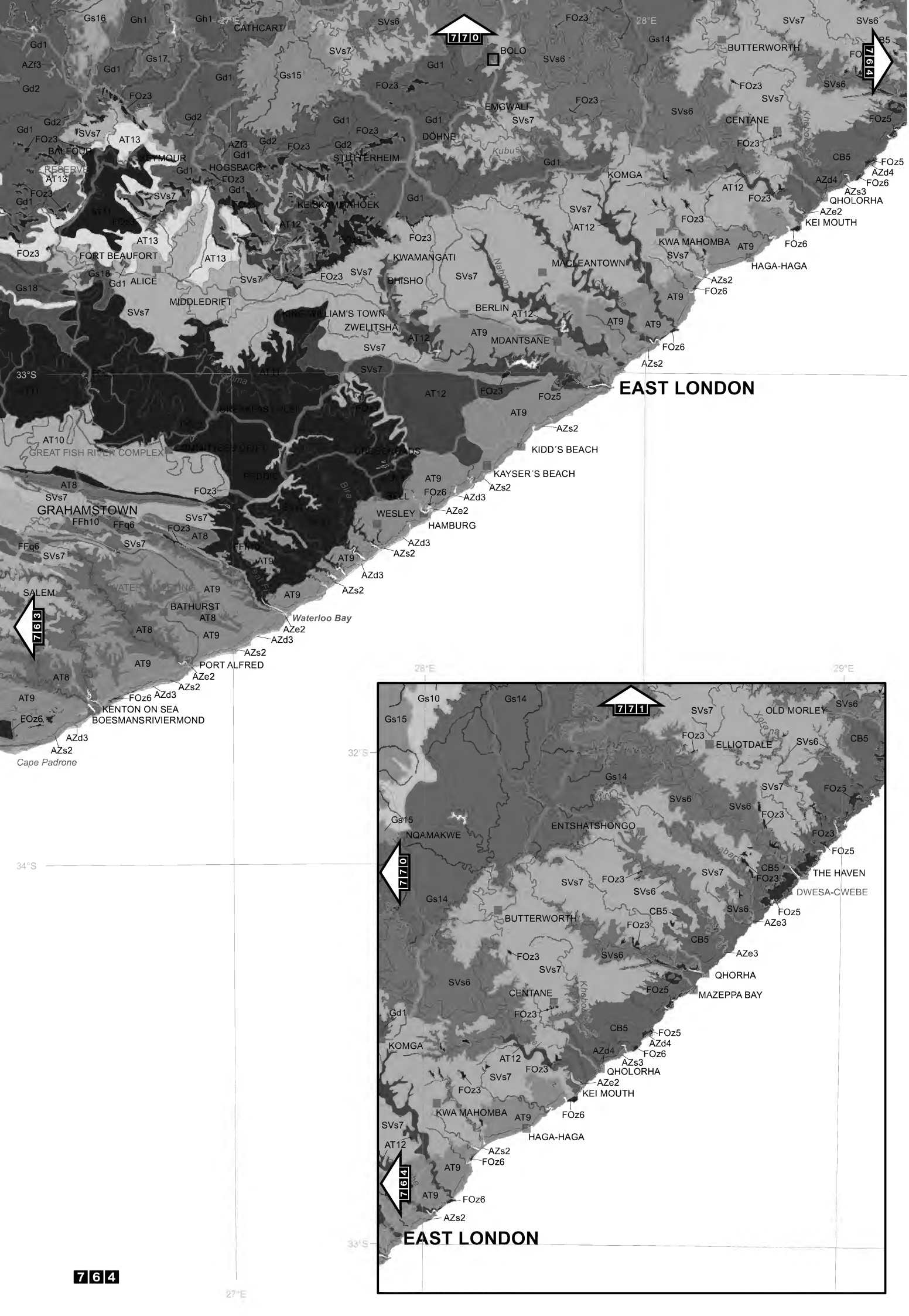
764
763



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771
EAST LONDON
BOLO
CATHCART
BUTTERWORTH
EMGWALI
DÖHNE
CENTANE
KOMGA
STUTTERHEIM
HOGSBACK
KEISKAMMAHOEK
KWA MAHOMBA
QHOLORHA
KEI MOUTH
HAGA-HAGA
MACLEANTOWN
KWAMANGATI
BHISHO
BERLIN
MDANTSANE
FORT BEAUFORT
ALICE
MIDDLEDRIFT
KING WILLIAM'S TOWN
ZWELITSHA
KIDD´S BEACH
KAYSER´S BEACH
WESLEY
HAMBURG
GREAT FISH RIVER COMPLEX
GRAHAMSTOWN
SALEM
BATHURST
Waterloo Bay
PORT ALFRED
KENTON ON SEA
BOESMANSRIVIERMOND
Cape Padrone
28°E
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OLD MORLEY
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NQAMAKWE
ENTSHATSHONGO
THE HAVEN
DWESA-CWEBE
QHORHA
MAZEPPA BAY

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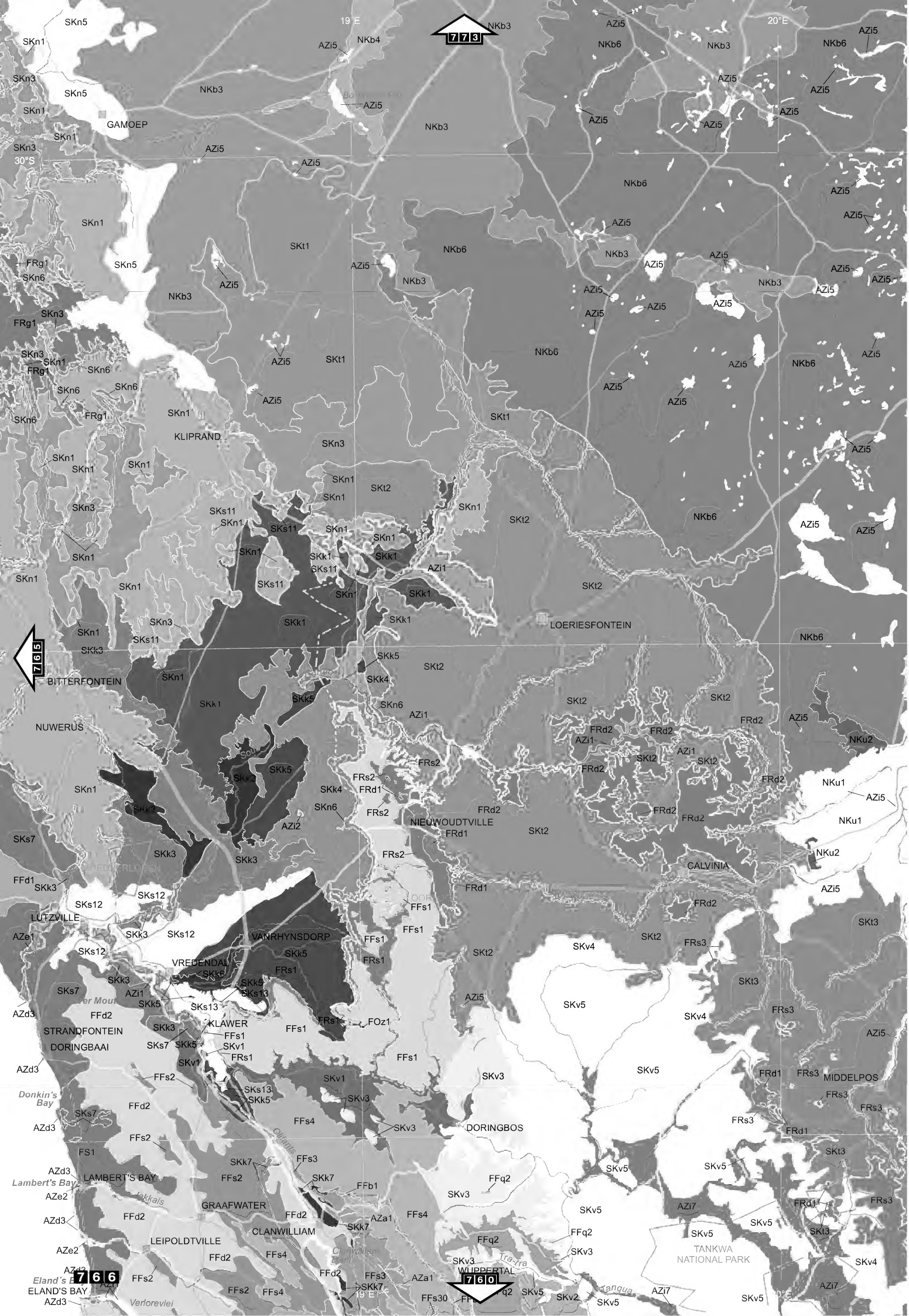
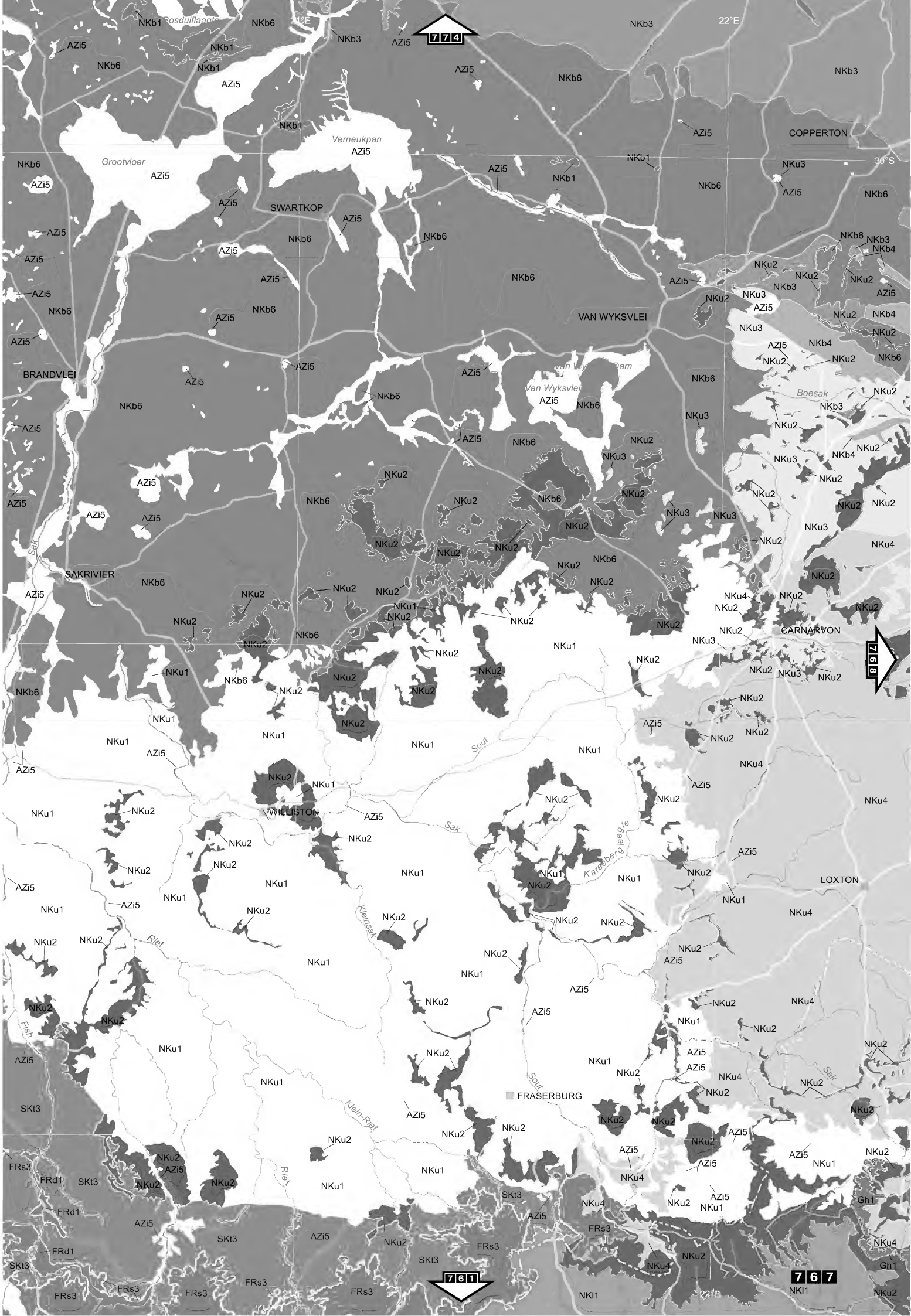
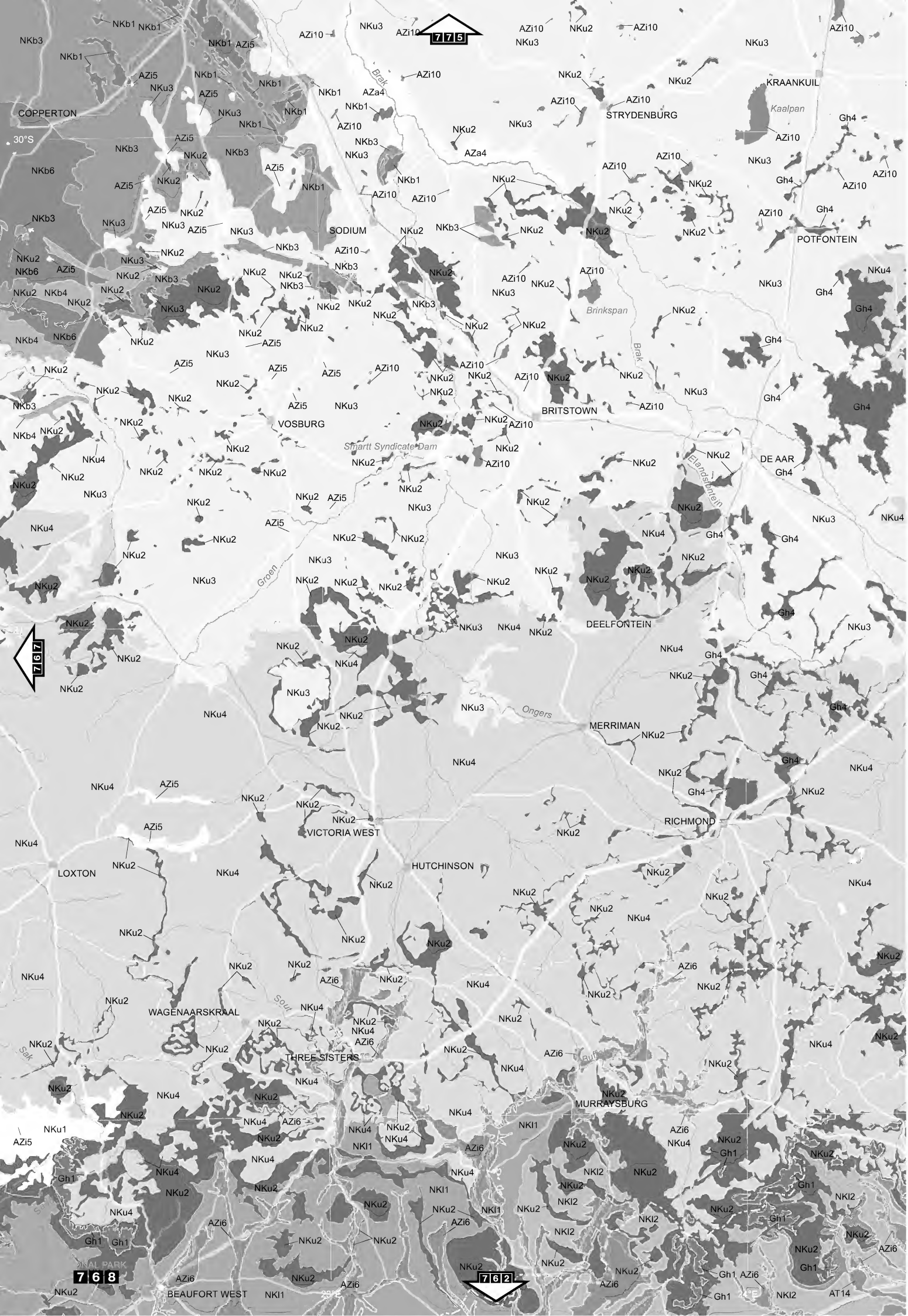
772
KLEINSEE
Stompneus Bay
Melkbospunt
Swartklip
NABABEEP
SPRINGBOK
CAROLUSBERG
KOMAGGAS
NAMAQUA NATIONAL PARK
SOEBATSFONTEIN
KOINGNAAS
KAMIESKROON
Hondeklip Bay
HONDEKLIPBAAI
Platklippunt
WALLEKRAAL
SPOEGRIVIER
LELIEFONTEIN
KARKAMS
Spoeg
Bitter
GARIES
Plat Bay
Groen
Island Point
KOTZESRUS
RIETPOORT
Langklip
BITTERFONTEIN
Sout
Blinkwater Bay
Olifants River Mouth
STRANDFONTEIN
DORINGBAAI
Donkin's Bay
Lambert's Bay
765
18°E
33°S
LEIPOLDTVILLE
Verlorevlei
REDELINGHUYS
St. Helena Bay
ST. HELENA BAY
PATERNOSTER
VELDDRIF
AURORA
VREDENBURG
Berg
SALDANHA
Saldanha Bay
LANGEBAAN
HOPEFIELD
Langebaan Lagoon
WEST COAST NATIONAL PARK
YZERFONTEIN
Yzerfonteinpunt
DARLING
Dassen Island
760

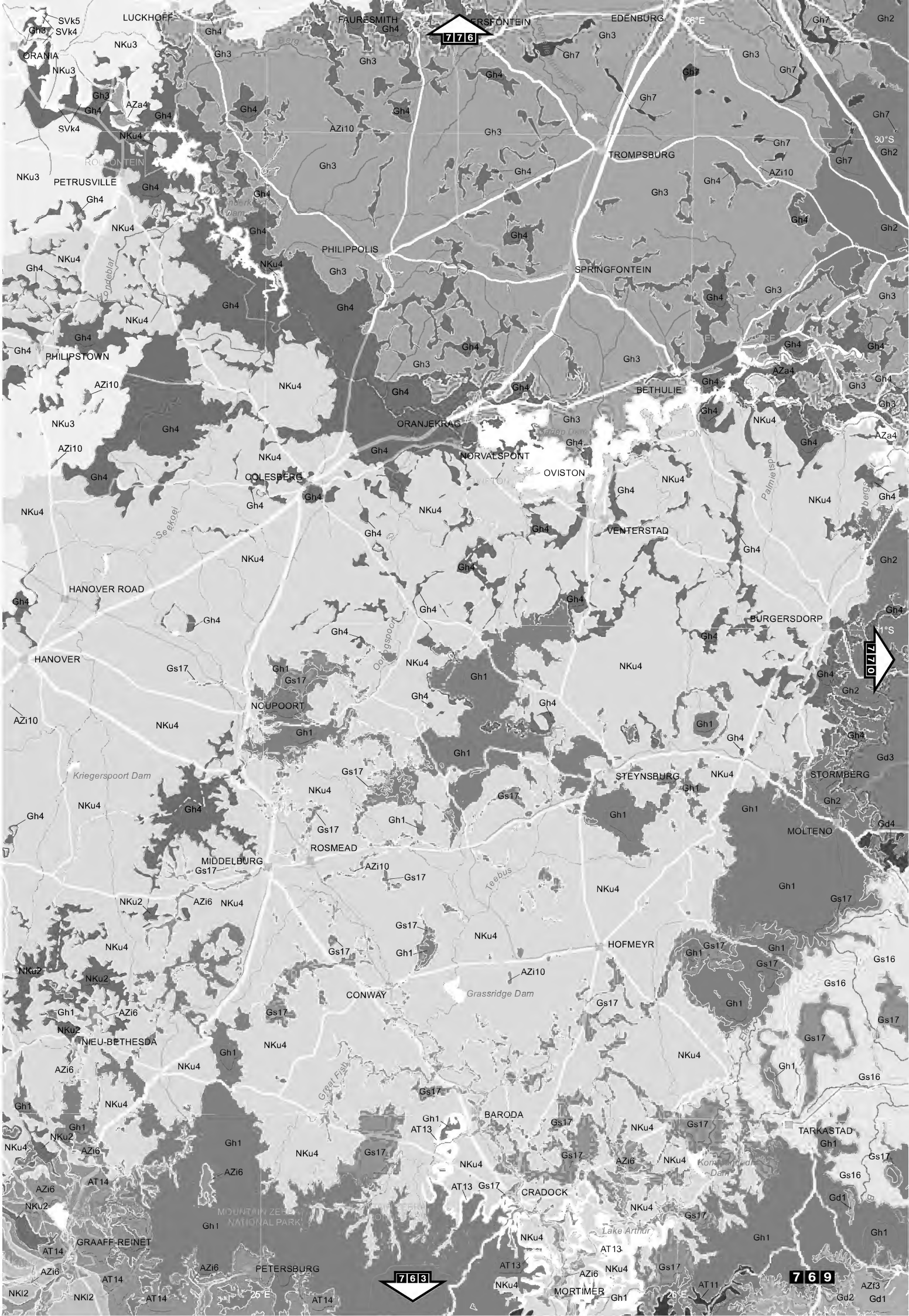

19°E
20°E
30°S
773
765
766
760
GAMOEP
KLIPRAND
LOERIESFONTEIN
BITTERFONTEIN
NUWERUS
NIEUWOUDTVILLE
CALVINIA
LUTZVILLE
VANRHYNSDORP
VREDENDAL
KLAWER
STRANDFONTEIN
DORINGBAAI
LAMBERT'S BAY
GRAAFWATER
CLANWILLIAM
LEIPOLDTVILLE
ELAND'S BAY
WUPPERTAL
DORINGBOS
MIDDELPOS
TANKWA
NATIONAL PARK
Donkin's Bay
Lambert's Bay
Eland's Bay
Verlorevlei
Olifants
Tra-tra
Tanqua
SKn5
SKn1
SKn3
SKn6
SKt1
SKt2
SKt3
NKb3
NKb4
NKb6
AZi5
AZi1
AZi7
FRg1
SKk1
SKk3
SKk4
SKk5
SKk6
SKk7
SKs11
SKs12
SKs13
FRs1
FRs2
FRs3
FRd1
FRd2
FFs1
FFs2
FFs3
FFs4
FFs30
FFd1
FFd2
FFb1
FFq2
SKv1
SKv2
SKv3
SKv4
SKv5
AZe1
AZe2
AZd3
NKu1
NKu2
FOz1



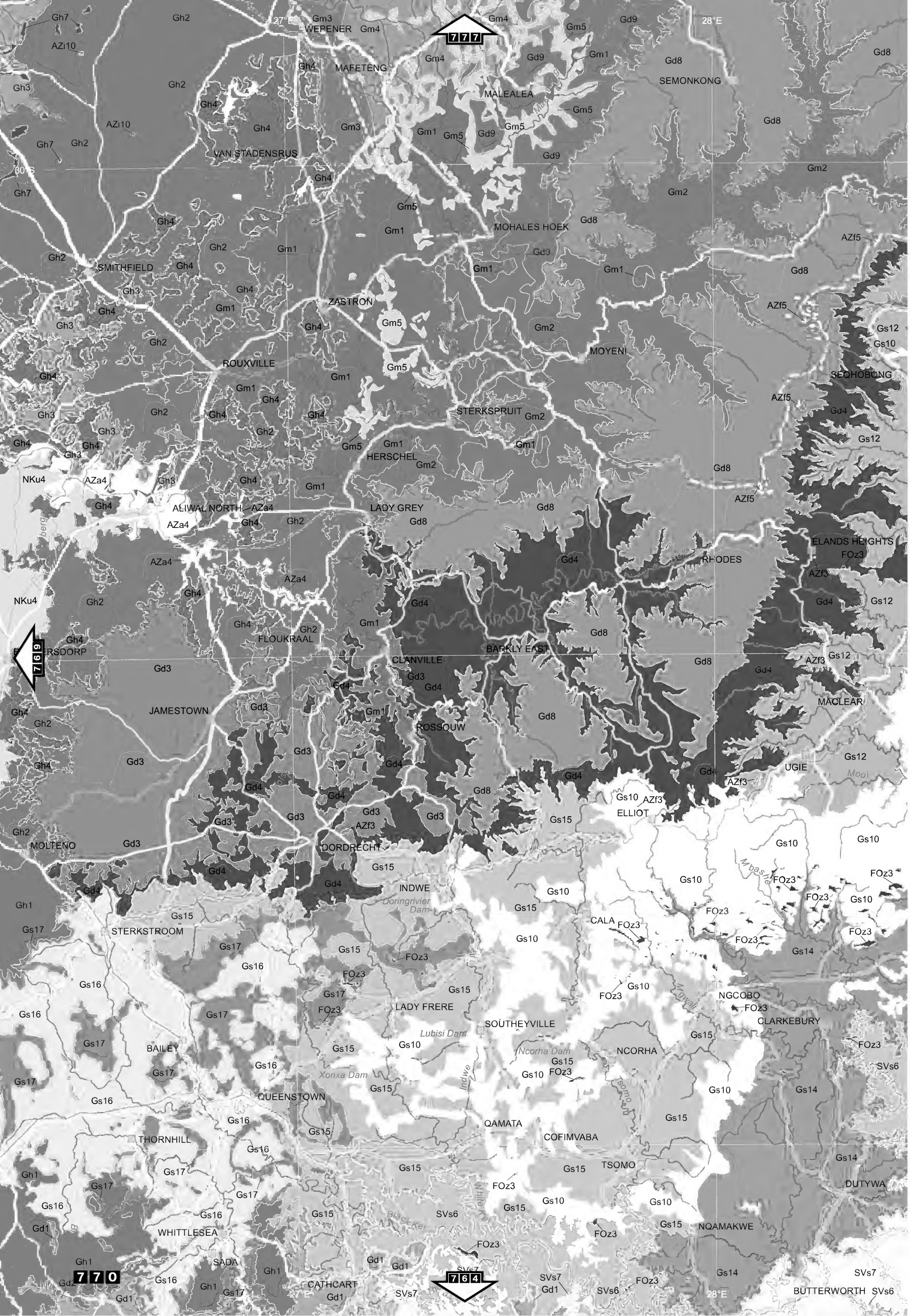
774
768
761
767
22°E
30°S
Bosduiflaagte
Verneukpan
Grootvloer
SWARTKOP
COPPERTON
VAN WYKSVLEI
BRANDVLEI
Van Wyksvlei
Boesak
SAKRIVIER
CARNARVON
WILLISTON
LOXTON
FRASERBURG
Sak
Sout
Kareeberg leegte
Kleinsak
Riet
Fish
Klein-Riet
NKb1
NKb3
NKb4
NKb6
AZi5
NKu1
NKu2
NKu3
NKu4
SKt3
FRs3
FRd1
Gh1
NKl1

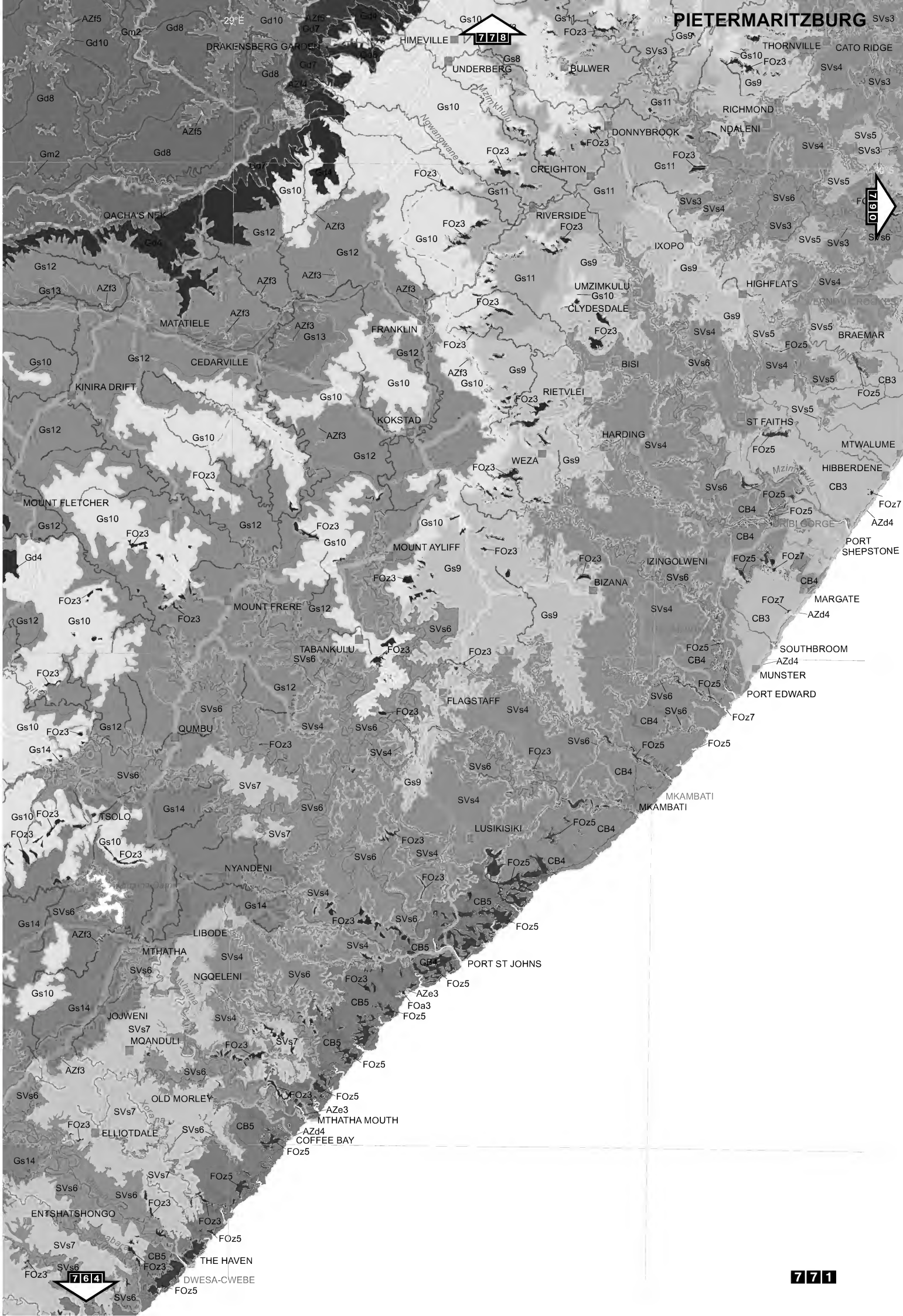


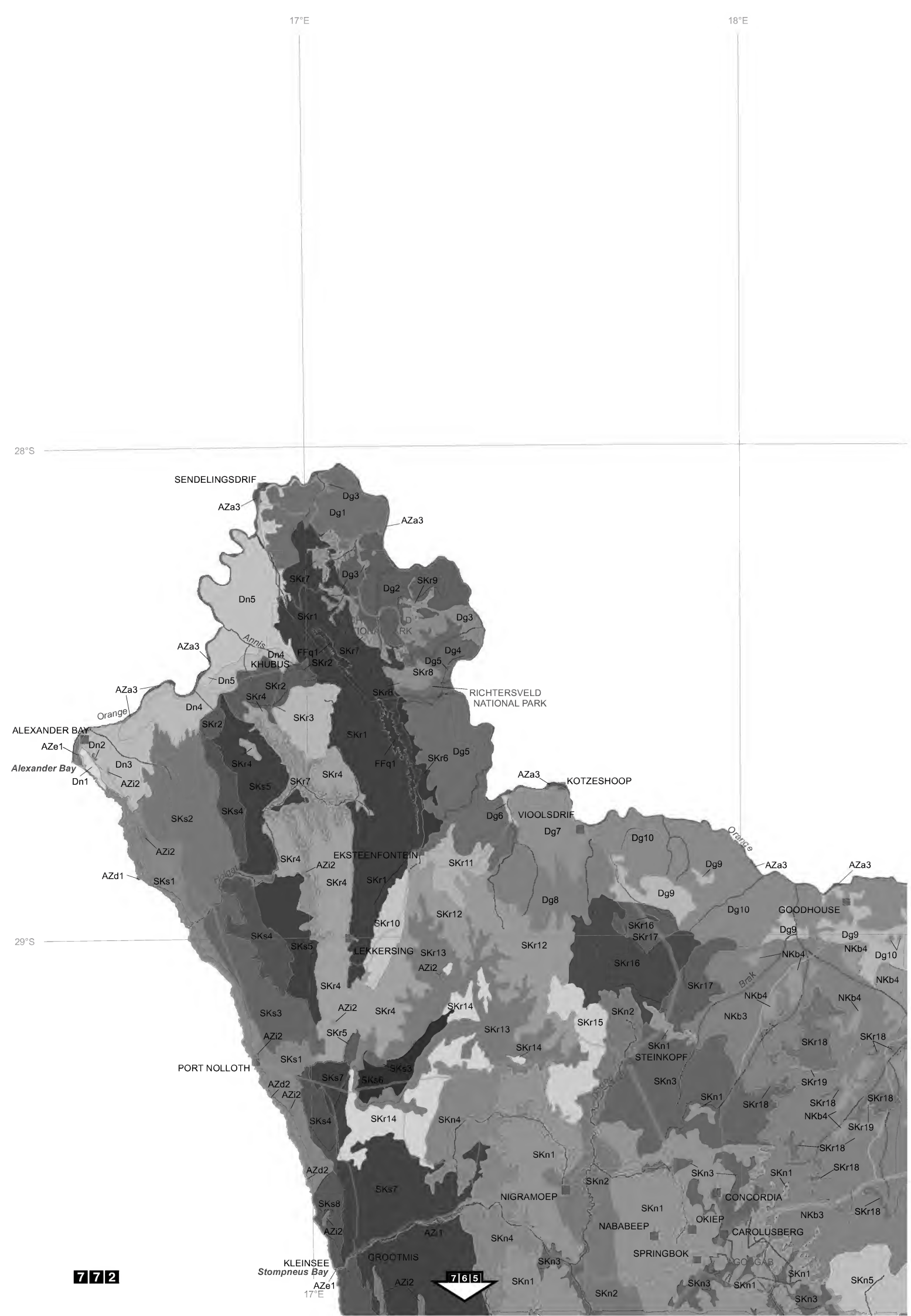
775
767
768
762
COPPERTON
30°S
SODIUM
STRYDENBURG
KRAANKUIL
Kaalpan
POTFONTEIN
Brinkspan
Brak
BRITSTOWN
VOSBURG
Smartt Syndicate Dam
DE AAR
Elandsfontein
Groen
DEELFONTEIN
Ongers
MERRIMAN
RICHMOND
VICTORIA WEST
HUTCHINSON
LOXTON
WAGENAARSKRAAL
Sout
THREE SISTERS
Sak
MURRAYSBURG
BEAUFORT WEST

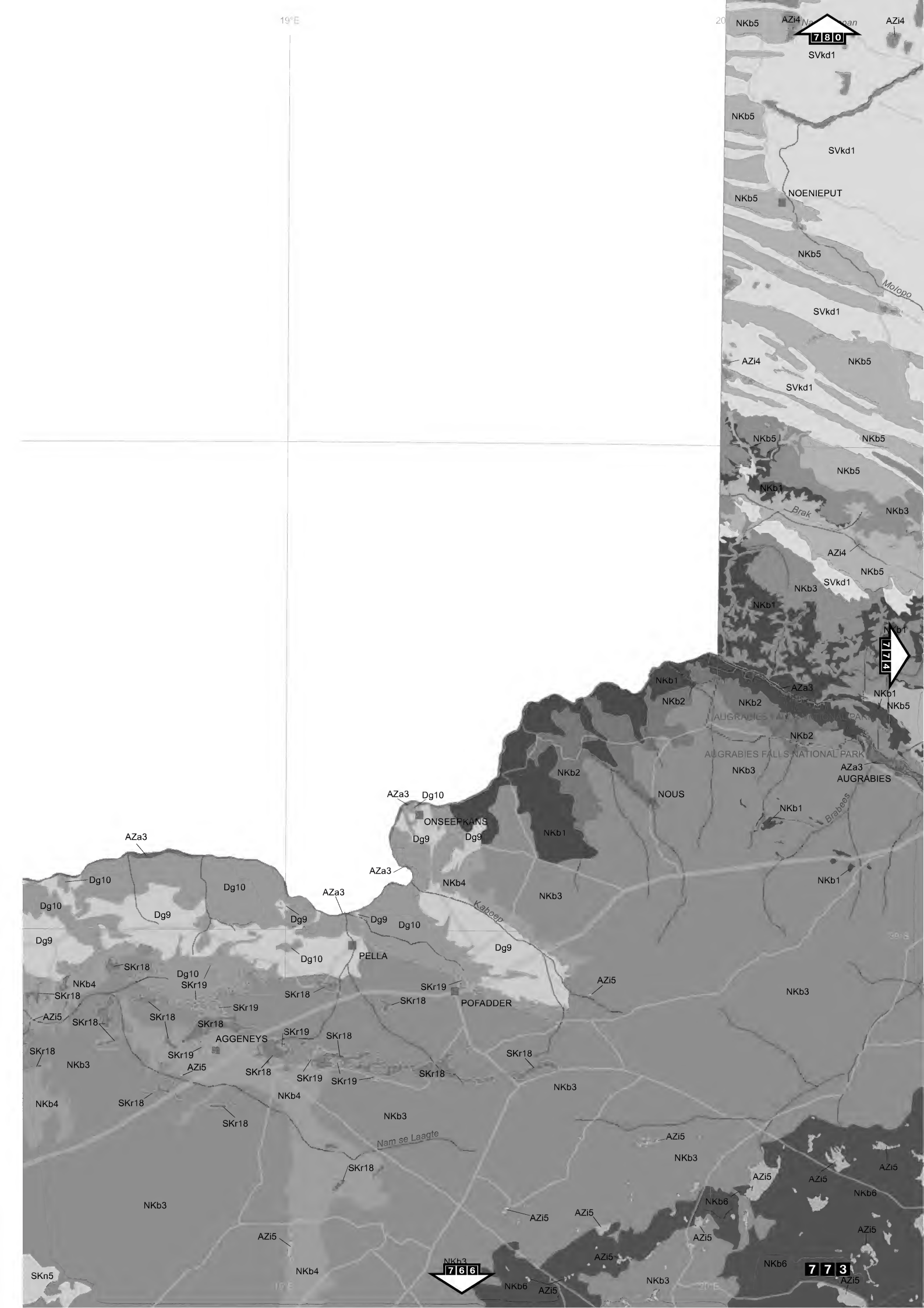


LUCKHOFF
FAURESMITH
EDENBURG
ORANIA
TROMPSBURG
PETRUSVILLE
PHILIPPOLIS
SPRINGFONTEIN
PHILIPSTOWN
BETHULIE
ORANJEKRAG
NORVALSPONT
OVISTON
COLESBERG
VENTERSTAD
HANOVER ROAD
BURGERSDORP
HANOVER
NOUPOORT
STEYNSBURG
STORMBERG
MOLTENO
ROSMEAD
MIDDELBURG
HOFMEYR
CONWAY
NIEU-BETHESDA
BARODA
TARKASTAD
CRADOCK
GRAAFF-REINET
PETERSBURG
MORTIMER
Kriegerspoort Dam
Grassridge Dam
Lake Arthur
Great Fish
Seekoei
Oorlogspoort
Teebus
Palmietspoort
26°E
30°S
31°S
25°E
776
770
763
769


27°E
28°E
WEPENER
MAFETENG
MALEALEA
SEMONKONG
VAN STADENSRUS
SMITHFIELD
ZASTRON
MOHALES HOEK
ROUXVILLE
MOYENI
SEQHOBONG
STERKSPRUIT
HERSCHEL
ALIWAL NORTH
LADY GREY
RHODES
ELANDS HEIGHTS
FLOUKRAAL
BARKLY EAST
CLANVILLE
MACLEAR
JAMESTOWN
ROSSOUW
UGIE
ELLIOT
MOLTENO
DORDRECHT
INDWE
STERKSTROOM
CALA
LADY FRERE
SOUTHEYVILLE
CLARKEBURY
NGCOBO
BAILEY
NCORHA
QUEENSTOWN
QAMATA
COFIMVABA
TSOMO
DUTYWA
NQAMAKWE
WHITTLESEA
SADA
CATHCART
BUTTERWORTH
Doringrivier Dam
Lubisi Dam
Ncorha Dam
Xonxa Dam
Indwe
Tsomo
Mbashe
Mooi
Black Kei
White Kei
777
769
770
764


PIETERMARITZBURG
778
790
764
771
HIMEVILLE
DRAKENSBERG GARDEN
UNDERBERG
BULWER
THORNVILLE
CATO RIDGE
RICHMOND
NDALENI
DONNYBROOK
CREIGHTON
RIVERSIDE
IXOPO
QACHA'S NEK
UMZIMKULU
CLYDESDALE
HIGHFLATS
MATATIELE
FRANKLIN
BRAEMAR
CEDARVILLE
BISI
KINIRA DRIFT
RIETVLEI
KOKSTAD
ST FAITHS
HARDING
MTWALUME
WEZA
HIBBERDENE
MOUNT FLETCHER
MOUNT AYLIFF
PORT SHEPSTONE
IZINGOLWENI
BIZANA
MARGATE
MOUNT FRERE
TABANKULU
SOUTHBROOM
MUNSTER
PORT EDWARD
FLAGSTAFF
QUMBU
MKAMBATI
TSOLO
LUSIKISIKI
NYANDENI
LIBODE
MTHATHA
PORT ST JOHNS
NGQELENI
JOJWENI
MQANDULI
OLD MORLEY
MTHATHA MOUTH
ELLIOTDALE
COFFEE BAY
ENTSHATSHONGO
THE HAVEN
DWESA-CWEBE


17°E
18°E
28°S
29°S
SENDELINGSDRIF
AZa3
Dg3
Dg1
AZa3
SKr7
Dg3
Dg2
SKr9
Dn5
SKr1
Dg3
Annis
AZa3
Dn4
KHUBUS
FFq1
SKr7
SKr2
Dg4
Dg5
SKr8
Dn5
SKr2
SKr4
SKr8
RICHTERSVELD
NATIONAL PARK
AZa3
Orange
Dn4
SKr3
ALEXANDER BAY
SKr2
SKr1
AZe1
Dn2
Dg5
Alexander Bay
Dn3
SKr4
FFq1
SKr6
Dn1
AZi2
SKr4
SKs5
SKr7
AZa3
KOTZESHOOP
SKs2
SKs4
Dg6
VIOOLSDRIF
Dg7
Dg10
Orange
AZi2
SKr4
EKSTEENFONTEIN
SKr11
Dg9
AZa3
AZa3
AZd1
SKs1
AZi2
SKr4
SKr1
Dg9
Dg8
Dg10
GOODHOUSE
SKr12
SKr10
SKr16
SKr17
Dg9
Dg9
SKs4
SKs5
LEKKERSING
SKr13
SKr12
NKb4
NKb4
Dg10
AZi2
SKr16
NKb4
SKr4
SKr17
Brak
NKb4
NKb4
SKs3
AZi2
SKr4
SKr14
SKn2
NKb3
SKr15
SKr13
AZi2
SKr5
SKr14
SKn1
SKr18
SKr18
SKs1
STEINKOPF
PORT NOLLOTH
SKs3
SKs7
SKs6
SKn3
SKr19
AZd2
AZi2
SKn1
SKr18
SKr18
SKr18
NKb4
SKs4
SKr14
SKn4
SKr19
SKr18
SKn1
AZd2
SKn3
SKn1
SKr18
SKs7
SKn2
NIGRAMOEP
CONCORDIA
SKs8
SKn1
NKb3
SKr18
OKIEP
AZi2
AZi1
NABABEEP
CAROLUSBERG
SKn4
SPRINGBOK
KLEINSEE
GROOTMIS
SKn3
Stompneus Bay
AZe1
AZi2
SKn1
SKn3
SKn1
SKn5
SKn2
SKn3
17°E
772
765



19°E
20°E
NKb5
AZi4
780
SVkd1
NOENIEPUT
Molopo
Brak
NKb3
NKb1
774
AZa3
NKb2
AUGRABIES FALLS NATIONAL PARK
AUGRABIES
NOUS
Brabees
Dg10
ONSEEPKANS
Dg9
Kaboep
NKb4
PELLA
SKr18
SKr19
POFADDER
AZi5
AGGENEYS
Nam se Laagte
NKb6
SKn5
766
773

781
773
774
767
Groot-Aarpan
Kongapan
Eensaamheidpan
Molopo
Groot-Witpan
Filanderspan
PEARSON´S HUNT
GELUKSPRUIT
LUTZPUTS
SULTANAOORD
Orange
KAROS
UPINGTON
STRAUSSBURG
GROOTDRINK
LOUISVALE
KANONEILAND
KALKWERF
AUGRABIES
LOXTONVALE
KEIMOES
MARCHAND
NEILERSDRIF
KAKAMAS
GROBLERSHOOP
BOEGOEBERG
PUTSONDERWATER
KENHARDT
WESTERBERG
DRAGHOENDER
MARYDALE
Fosduiflaagte
29°S
21°E
22°E
SVkd1
SVkd2
AZi4
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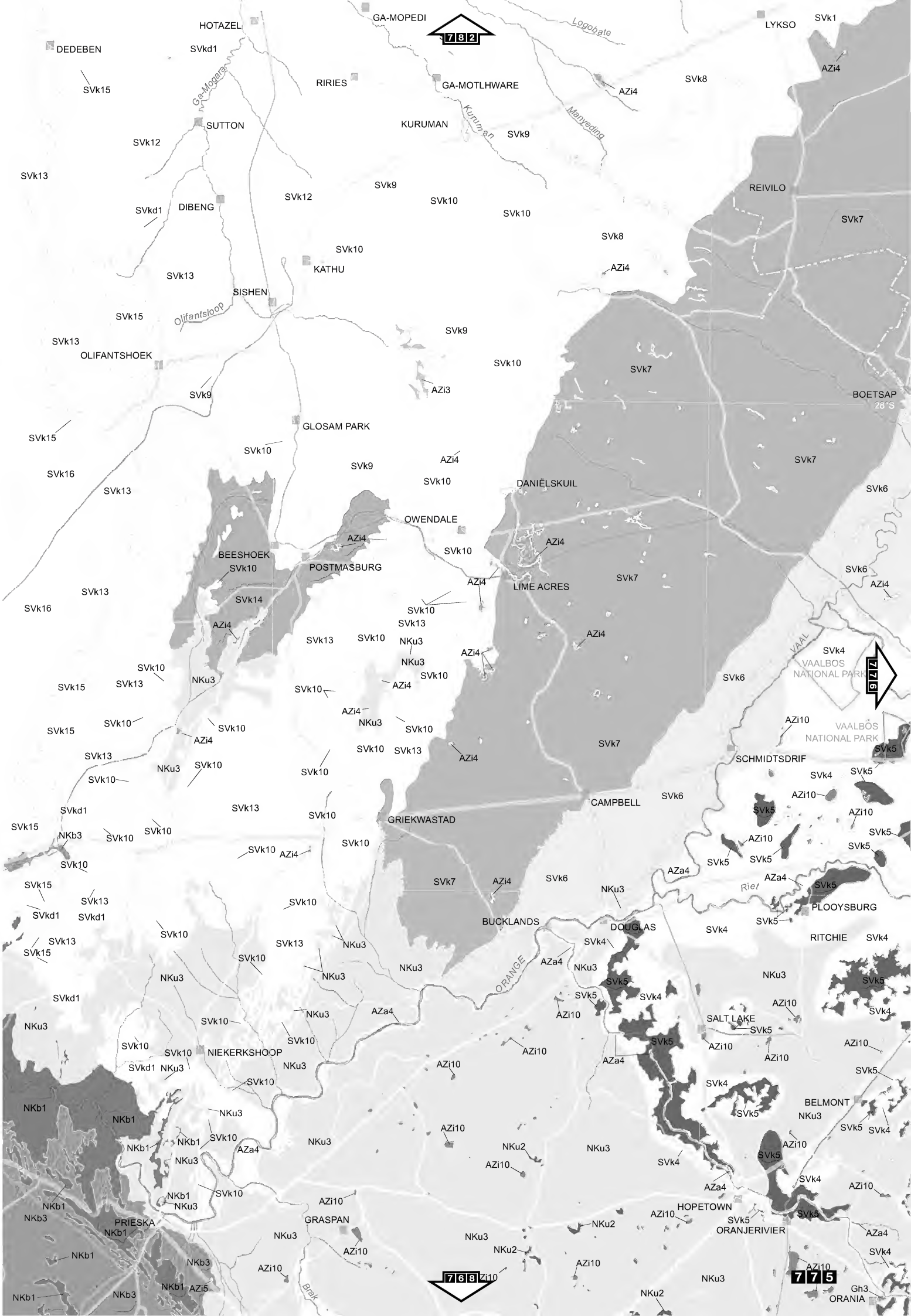
SVk13
SVk15
NKb5
NKb3
NKb1
NKb6
AZa3
AZi5
NKu3



782
GA-MOPEDI
HOTAZEL
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Ga-Mogara
RIRIES
GA-MOTLHWARE
Logobate
LYKSO
SVk1
AZi4
SVk8
AZi4
SUTTON
KURUMAN
Kuruman
Manyeding
SVk9
SVk12
SVk13
SVk9
SVk12
SVk10
SVk10
REIVILO
SVk7
SVkd1
DIBENG
SVk8
SVk10
KATHU
AZi4
SVk13
SISHEN
SVk15
Olifantsloop
SVk9
SVk13
OLIFANTSHOEK
SVk10
SVk7
AZi3
SVk9
BOETSAP
28°S
GLOSAM PARK
SVk15
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AZi4
SVk7
SVk16
SVk9
SVk10
DANIËLSKUIL
SVk6
SVk13
OWENDALE
AZi4
AZi4
BEESHOEK
SVk10
SVk10
POSTMASBURG
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AZi4
LIME ACRES
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SVk13
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SVk13
AZi4
SVk13
SVk10
NKu3
AZi4
AZi4
VAAL
SVk4
VAALBOS
NATIONAL PARK
776
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AZi4
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NKu3
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SVkd1
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NKu3
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NKu3
AZa4
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NKb3
PRIESKA
GRASPAN
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SVk5
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NKb1
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NKu2
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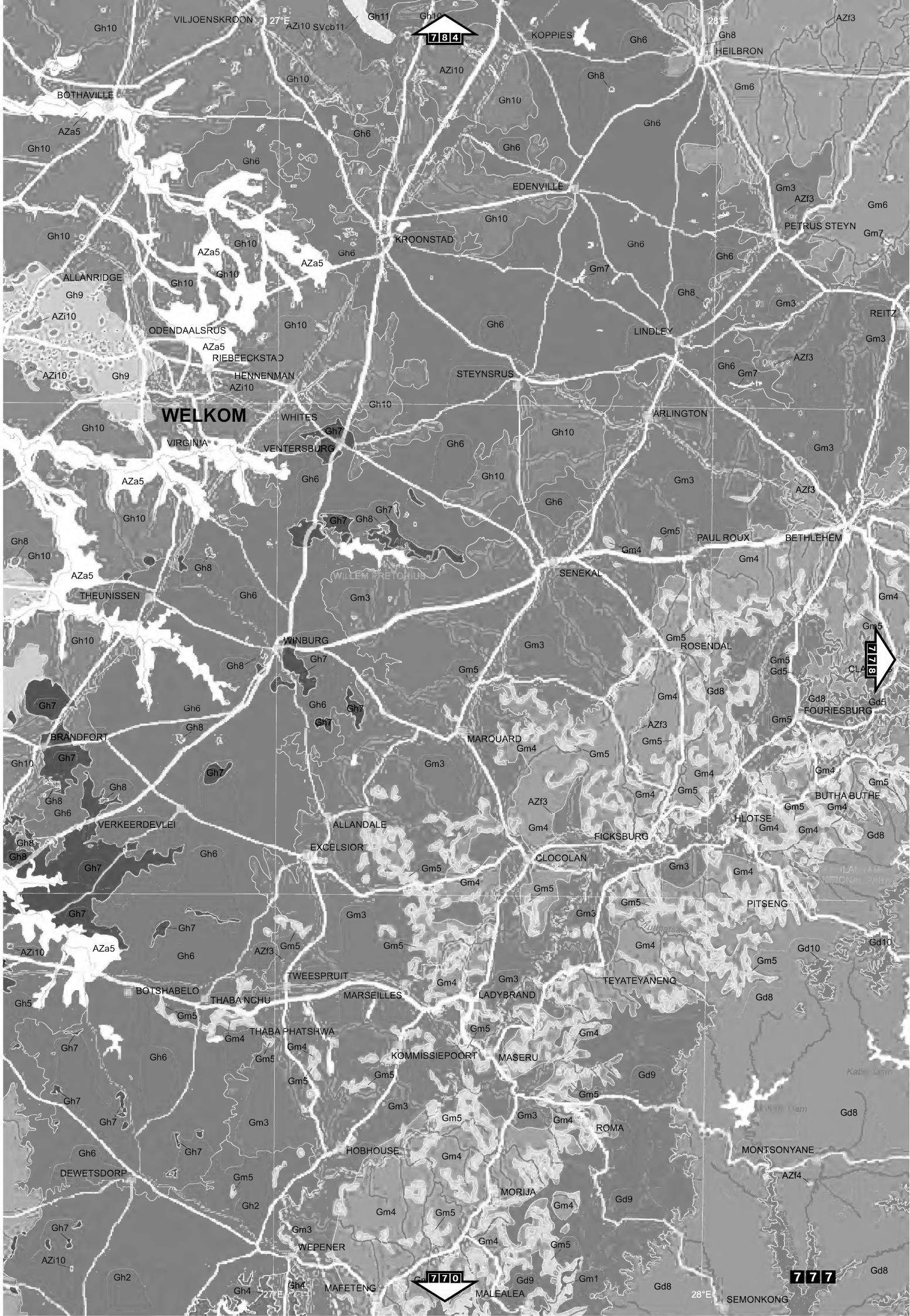
AZi10
AZi10
768
Zi10
775
NKb1
NKb3
NKb1
AZi5
Brak
NKu3
Gh3
ORANIA
NKu2

25°E
26°E
28°S
SCHWEIZER-RENEKE
WOLMARANSSTAD
LEEUDORINGSTAD
MAKWASSIE
AVONDSTER
MARUBISENG
TAUNG
BLOEMHOF
Bloemhof Dam
VAALBOSCHHOEK
PAMPIERSTAD
HARTSWATER
HOOPSTAD
CHRISTIANA
JAN KEMPDORP
BOETSAP
WARRENTON
Spitskop Dam
HERTZOGVILLE
WINDSORTON
WINDSORTON ROAD
BULTFONTEIN
BARKLY WEST
BOSHOF
Annaspan
DEALESVILLE
SOUTPAN
VAALBOS NATIONAL PARK
KIMBERLEY
WOLWEDRIFT
RITCHIE
Modder
JACOBSDAL
PETRUSBURG
BLOEMFONTEIN
BELMONT
KOFFIEFONTEIN
Kalkfontein Dam
LUCKHOFF
JAGERSFONTEIN
EDENBURG
REDDERSBURG
FAURESMITH
ORANIA
Harts
VAAL
Riet
783
775
776
769



VILJOENSKROON
27°E
28°E
784
KOPPIES
HEILBRON
BOTHAVILLE
EDENVILLE
PETRUS STEYN
KROONSTAD
ALLANRIDGE
ODENDAALSRUS
RIEBEECKSTAD
HENNENMAN
LINDLEY
REITZ
STEYNSRUS
WELKOM
WHITES
VIRGINIA
VENTERSBURG
ARLINGTON
PAUL ROUX
BETHLEHEM
SENEKAL
WILLEM PRETORIUS
THEUNISSEN
WINBURG
ROSENDAL
778
FOURIESBURG
BRANDFORT
MARQUARD
BUTHA BUTHE
HLOTSE
VERKEERDEVLEI
ALLANDALE
FICKSBURG
EXCELSIOR
CLOCOLAN
PITSENG
TWEESPRUIT
TEYATEYANENG
BOTSHABELO
THABA NCHU
MARSEILLES
LADYBRAND
THABA PHATSHWA
KOMMISSIEPOORT
MASERU
ROMA
HOBHOUSE
MONTSONYANE
DEWETSDORP
MORIJA
WEPENER
770
MAFETENG
MALEALEA
777
SEMONKONG

29°E
28°S
29°S
785
777
778
771
PERDEKOP
FRANKFORT
VREDE
TWEELING
VOLKSRUST
WAKKERSTROOM
GROENVLEI
UTRECHT
MEMEL
NEWCASTLE
MADADENI
OZIZWENI
REITZ
WARDEN
VERKYKERSKOP
NORMANDIEN
DANNHAUSER
Chelmsford Dam
KRANSFONTEIN
BETHLEHEM
KESTELL
HARRISMITH
GLENCOE
DUNDEE
WASBANK
CLARENS
PHUTHADITJHABA
GELUKSBURG
LADYSMITH
Woodstock Dam
BERGVILLE
COLENSO
WINTERTON
WEENEN
LOSKOP
FRERE
CATHEDRAL PEAK
CHAMPAGNE CASTLE
ESTCOURT
Wagendrift
MOOIRIVER
GIANT'S CASTLE
Karkloof Forest
MOKHOTLONG
NOTTINGHAM ROAD
HOWICK
Midmar Dam
IMPENDLE
THABA-TSEKA
MONTSONYANE
Mkhomazi

786
31°E
32°E
067
790
31°E
MAHAMBA
NHLANGANO
DIRKIESDORP
PAULPIETERSBURG
PONGOLA
JOZINI
Pongolapoort Dam
ITHALA GAME RESERVE
MAGUDU
LOUWSBURG
MKUZE
VRYHEID
HLOBANE
Ongome Forest
BLOEDRIVIER
KINGSLEY
NONGOMA
GLUCKSTADT
EMONDLO
HLUHLUWE
HLABISA
NQUTU
MAHLABATINI
BABANANGO
ULUNDI
ST LUCIA ESTUARY
MTUBATUBA
HELPMEKAAR
RIVERVIEW
Mfolozi
GREATER ST LUCIA WETLAND PARK
POMEROY
QUDENI
MELMOTH
NKANDLA
KWA MBONAMBI
NSELENI
TUGELA FERRY
NKWALINI
EMPANGENI
JAMESON'S DRIFT
KEATE'S DRIFT
FELIXTON
RICHARDS BAY
ESHOWE
Ongoye Forest
KRANSKOP
MTUNZINI
UMLALAZI
GREYTOWN
GINGINDLOVU
AMATIKULU
MAPUMULO
AMATHIKULU
SEVENOAKS
DARNALL
DALTON
NEW HANOVER
STANGER
ALBERT FALLS
WARTBURG
SHAKASKRAAL
TONGAAT
UMDLOTI
Gm12
FOz2
Gm15
Gm16
Gs2
Gm14
SVI14
SVI3
SVI4
SVI22
SVI23
SVI19
SVI21
SVI17
SVI16
SVI20
SVI18
FOz5
AZa7
FOz8
FOa1
AZf6
AZi11
Gs6
Gs1
Gs7
Gs5
AZf3
FOz3
CB1
FOa1
Gs8
Gs4
Gs3
Gs9
SVs4
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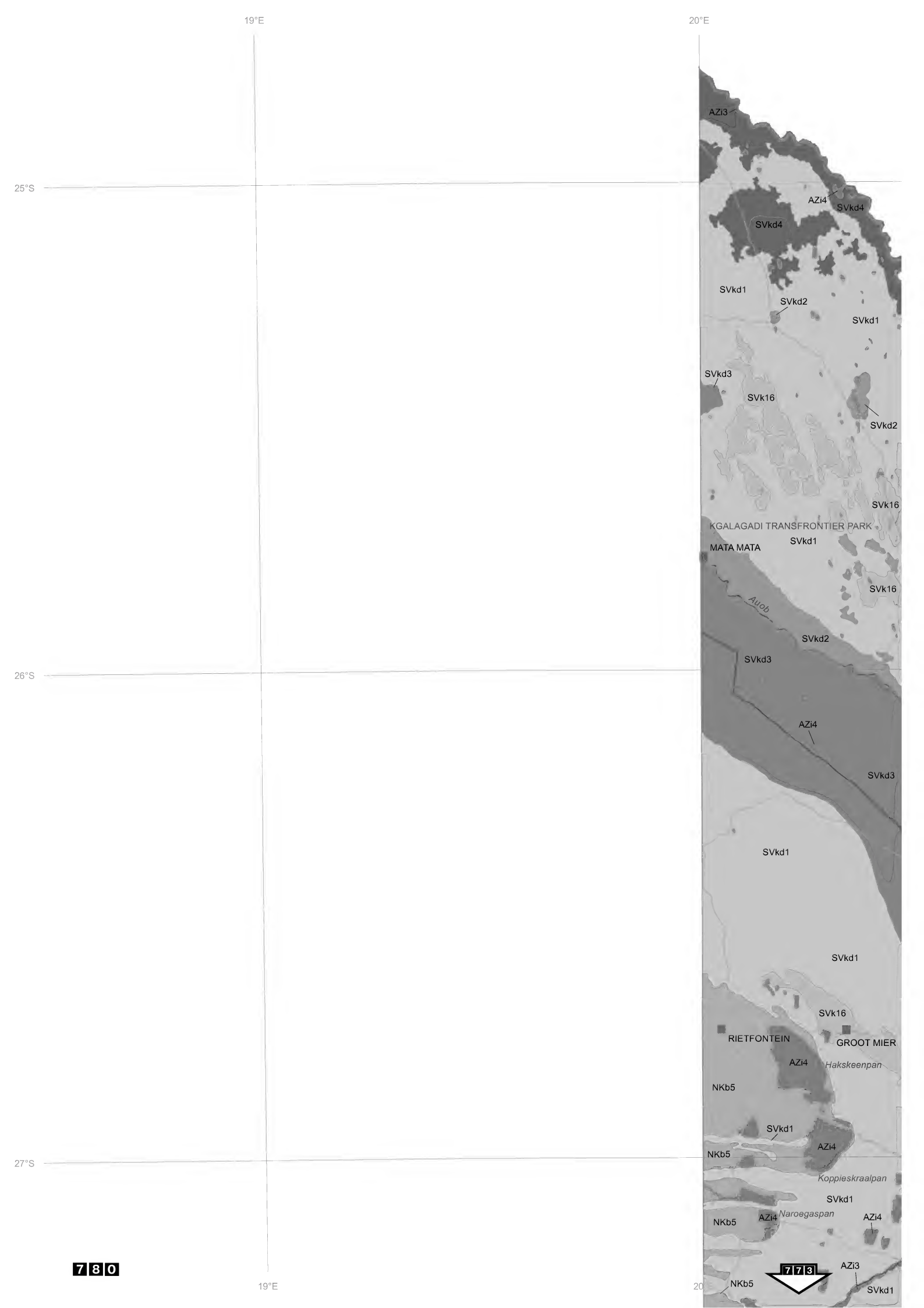
SVs5


19°E
20°E
25°S
26°S
27°S
AZi3
AZi4
SVkd4
SVkd4
SVkd1
SVkd2
SVkd1
SVkd3
SVk16
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Auob
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AZi4
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SVkd1
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RIETFONTEIN
GROOT MIER
AZi4
Hakskeenpan
NKb5
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AZi4
NKb5
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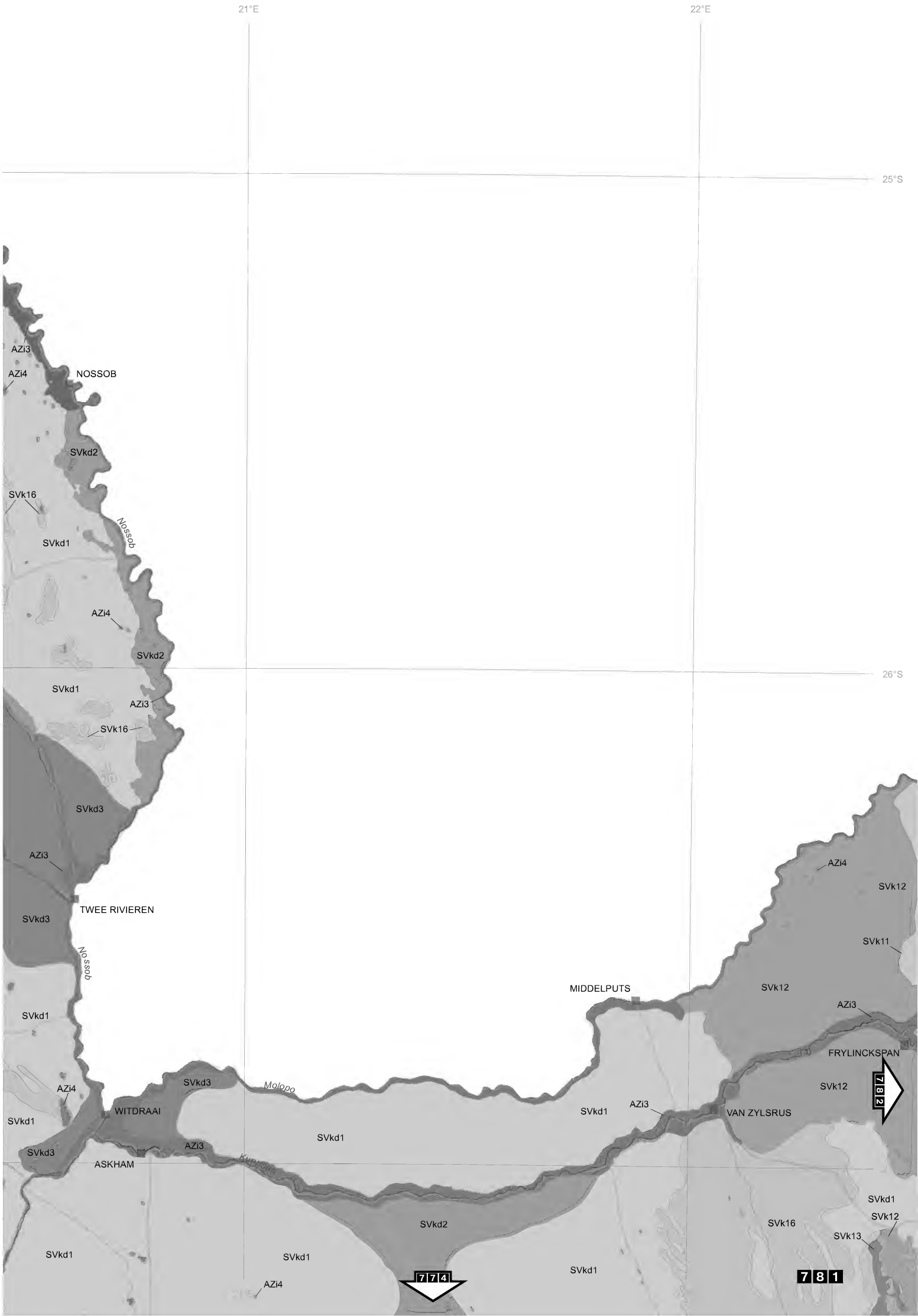
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AZi4
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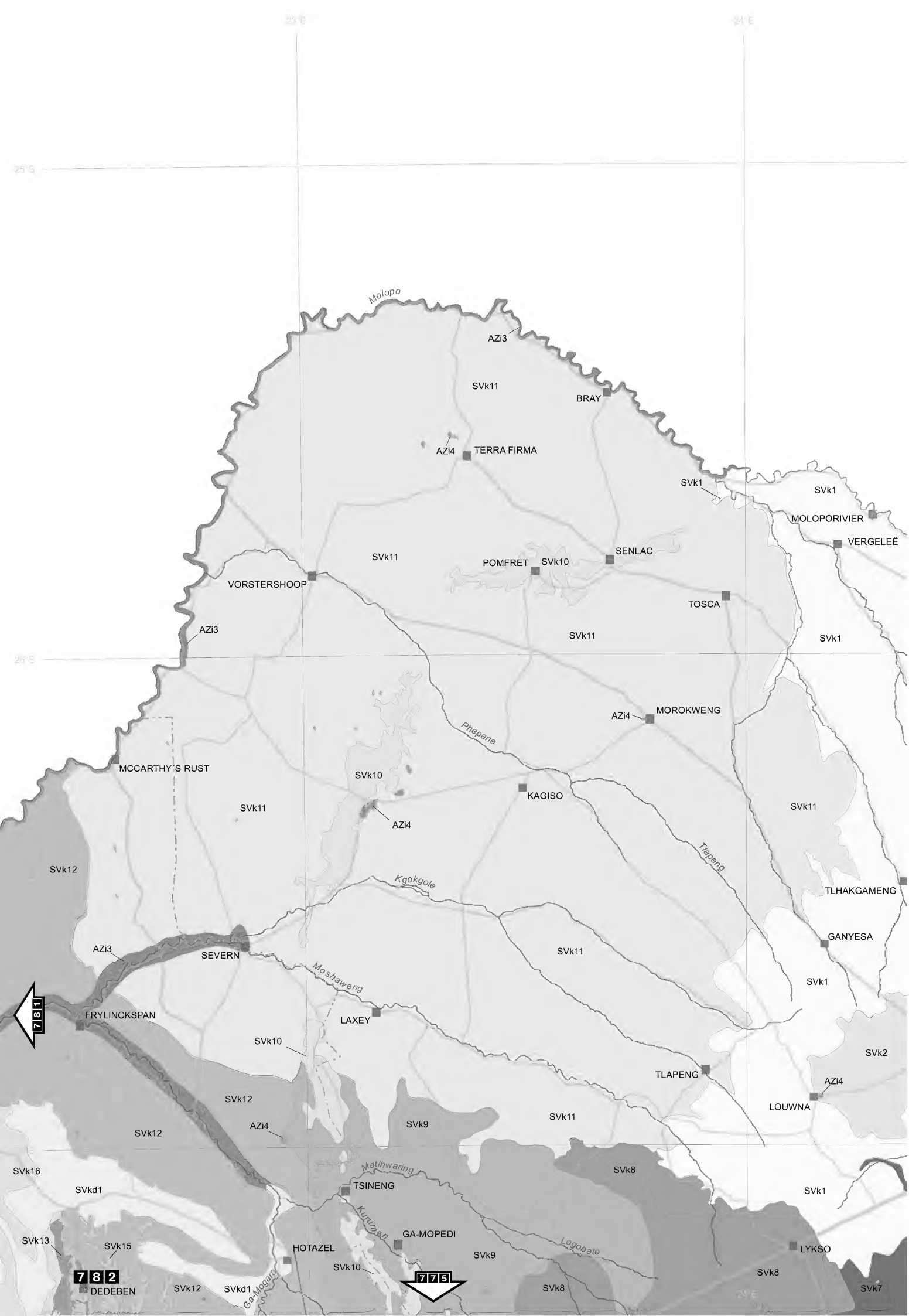
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POMFRET
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VORSTERSHOOP
TOSCA
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Phepane
MCCARTHY'S RUST
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GANYESA
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LAXEY
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Matlhwaring
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TSINENG
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Kuruman
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SVk15
GA-MOPEDI
HOTAZEL
SVk9
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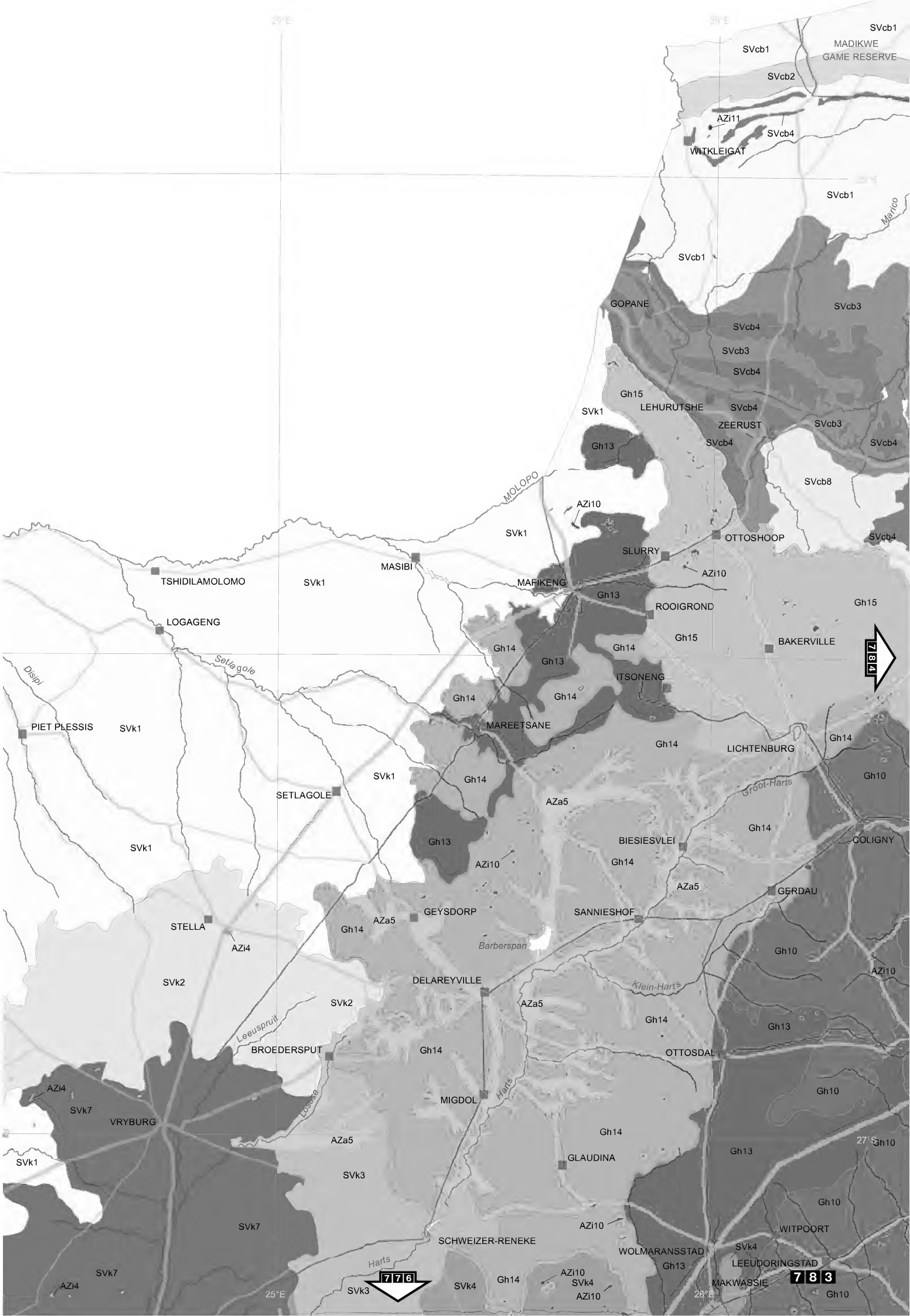

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ZEERUST
SVk1
Gh13
MOLOPO
SVcb8
AZi10
OTTOSHOOP
SLURRY
MASIBI
TSHIDILAMOLOMO
MAFIKENG
ROOIGROND
LOGAGENG
BAKERVILLE
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Setlagole
Disipi
ITSONENG
PIET PLESSIS
MAREETSANE
LICHTENBURG
SETLAGOLE
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Groot-Harts
BIESIESVLEI
COLIGNY
GERDAU
GEYSDORP
SANNIESHOF
STELLA
AZi4
Barberspan
DELAREYVILLE
Klein-Harts
SVk2
Leeuspruit
BROEDERSPUT
OTTOSDAL
Losase
Harts
MIGDOL
VRYBURG
GLAUDINA
SVk3
WITPOORT
SCHWEIZER-RENEKE
WOLMARANSSTAD
LEEUDORINGSTAD
MAKWASSIE
784
776
783
25°E
26°E
27°S

DERDEPOORT
MADIKWE GAME RESERVE
DWARSBERG
Molatedi Dam
Marico
NORTHAM
ROOIBERG
Klipvoor Dam
BORAKALALO
MABESKRAAL
PILANSBERG GAME RESERVE
Crocodile
Vaalkop Dam
Groot-Marico
SUN CITY
Elands
TSITSING
Rooikoppies Dam
PELLA
MABOPANE
PHOKENG
GA-RANKUWA
GROOT-MARICO
BRITS
SWARTRUGGENS
RUSTENBURG
Koster
Hartbeespoort Dam
PRETORIA
Hex
MAGALIESBERG
GROENKLOOF NATIONAL PARK
KOSTER
DERBY
Magalies
CENTURION
GROOTPAN
MAGALIESBURG
KRUGERSDORP
JOHANNESBURG
RANDFONTEIN
GA-RAMODINGWANA
Klerkskraal Dam
VENTERSPOS
KHUTSONG
VENTERSDORP
WESTONARIA
COLIGNY
CARLETONVILLE
EVATON
MEYERTON
SEBOKENG
VEREENIGING
POTCHEFSTROOM
VANDERBIJL PARK
HARTBEESFONTEIN
SASOLBURG
KLERKSDORP
PARYS
DENEYSVILLE
ORKNEY
VREDEFORT
ORANJEVILLE
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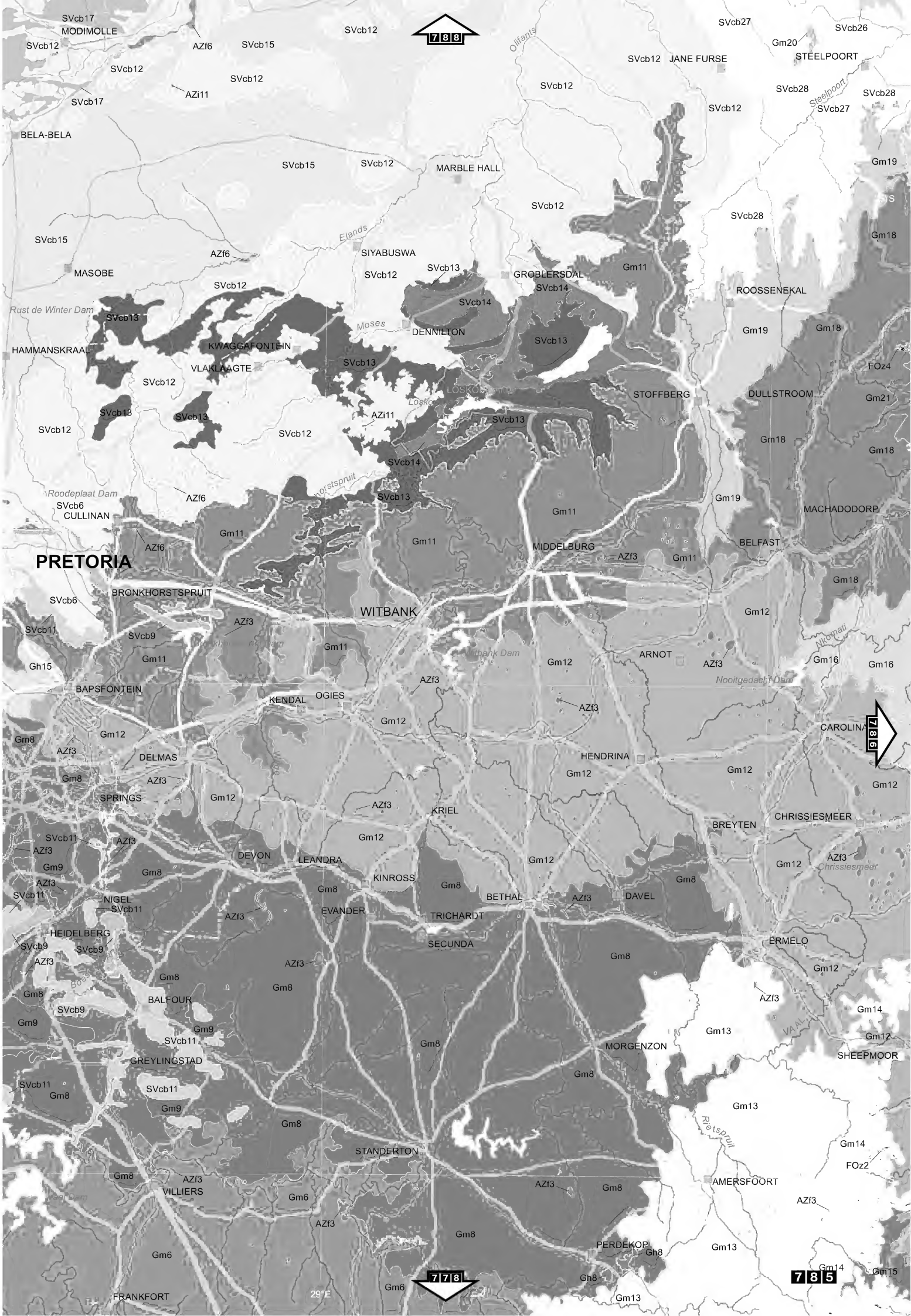
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BELA-BELA
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VILLIERS
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PERDEKOP
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Gm6
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Gm14
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Gh8
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788
Gm13
FRANKFORT
29°E

NELSPRUIT
KLASERIE
MOTLATSE RIVER
BURGERSFORT
OHRIGSTAD
PILGRIM´S REST
GRASKOP
BUSHBUCKRIDGE
SKUKUZA
HAZYVIEW
SABIE
LYDENBURG
PRETORIUSKOP
LOWER-SABIE
CROCODILE BRIDGE
WHITE RIVER
HECTORSPRUIT
KOMATIPOORT
MALELANE
KAAPSEHOOP
WATERVAL-BOVEN
MACHADODORP
SIBAYENI
BARBERTON
Vygeboom Dam
BADPLAAS
PIGG'S PEAK
TSHANENI
LOCHIEL
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WARBURTON
LAWULA
MBABANE
LOTHAIR
SITEKI
MANZINI
BHUNYA
AMSTERDAM
SHEEPMOOR
Morgenstond Dam
BIG BEND
NDUMO
PIET RETIEF
HLATHIKHULU
MAHAMBA
INGWAVUMA
Nkomati
Mpuluzi
Usutu
Westoe Dam
Jericho Dam
Heyshope Dam
Mnjoli Dam
Sand River Dam
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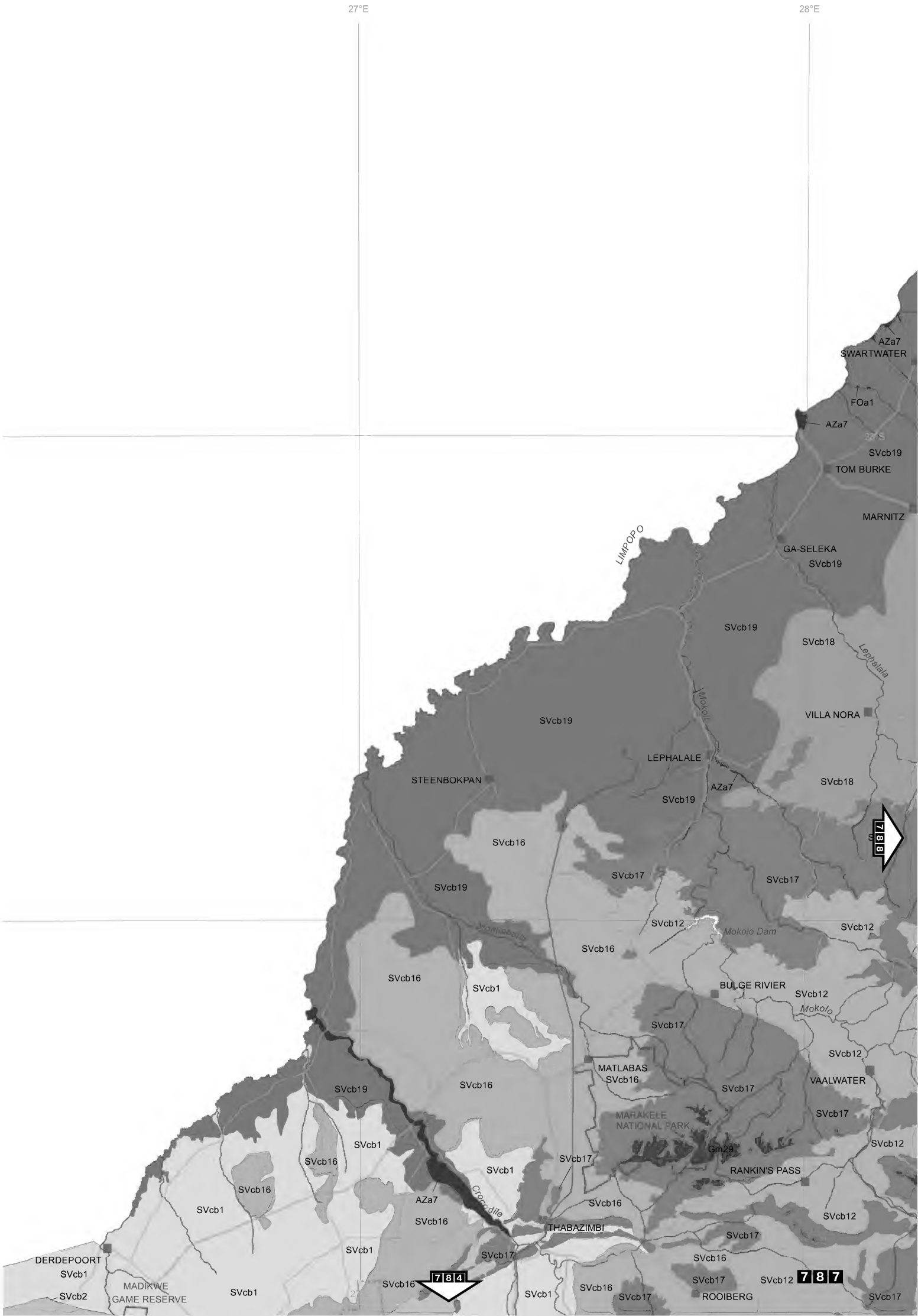
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STEENBOKPAN
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NATIONAL PARK
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Crocodile
SVcb1
SVcb16
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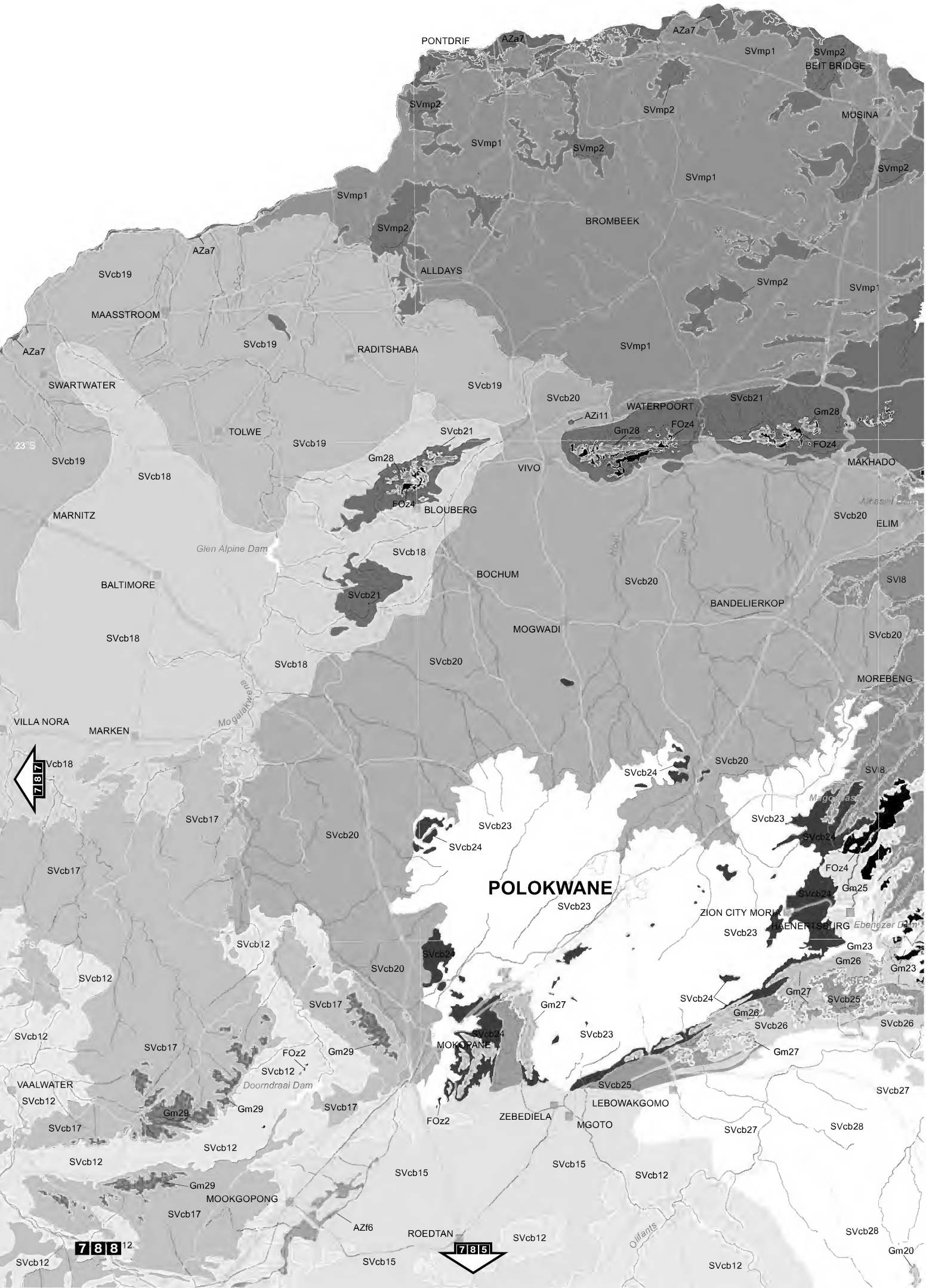
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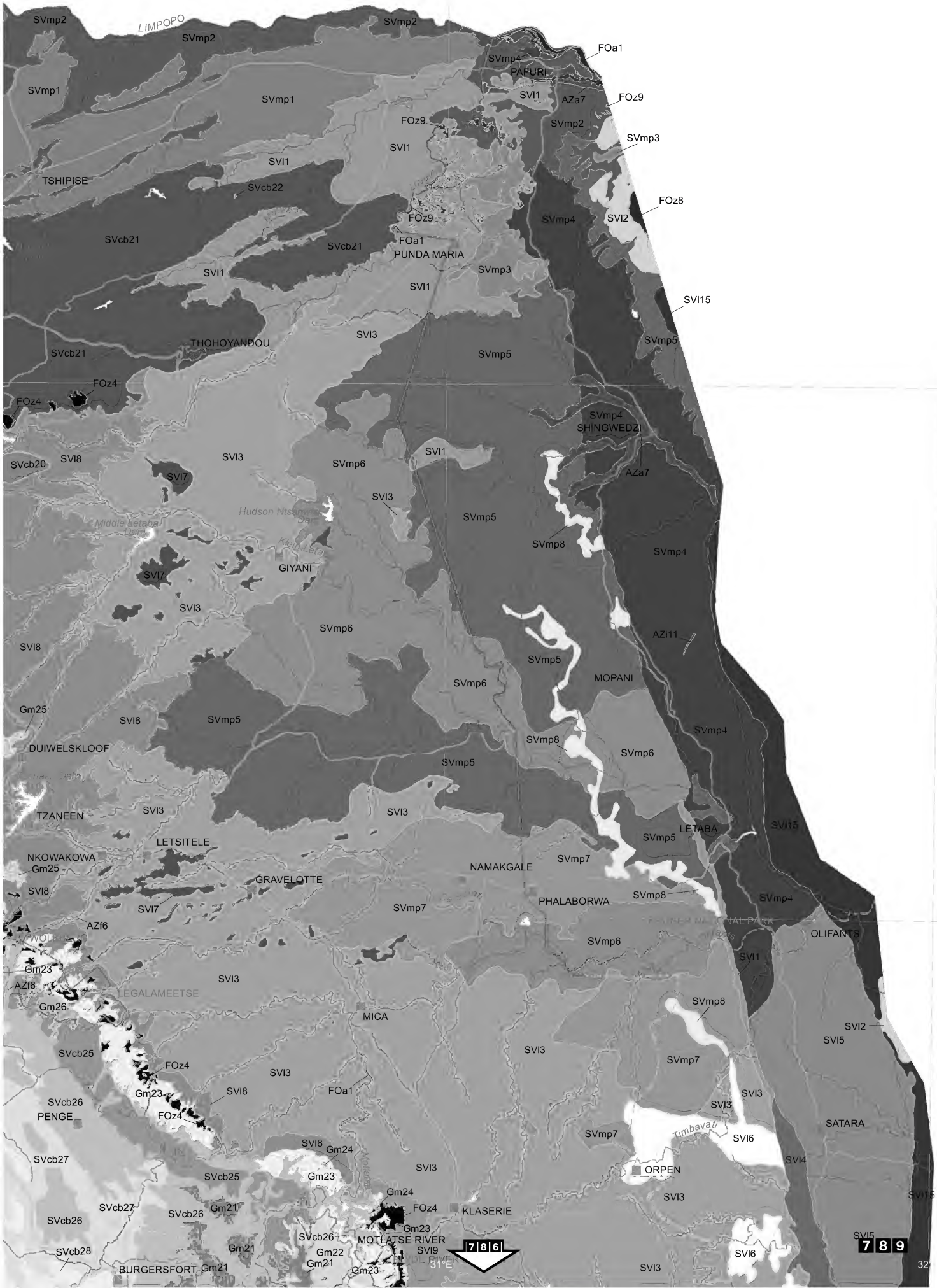
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789

DURBAN
TONGAAT
FOz7
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CATO RIDGE
CAMPERDOWN
UMALANGA
UMBUMBULU
AMANZIMTOTI
MAGABENI
UMKOMAAS
CROOKES
UMZINTO
SCOTTBURGH
BRAEMAR
PENNINGTON
SEZELA
MTWALUME
HIBBERDENE
PORT SHEPSTONE
Mlazi
Lovu
Mkomazi
32°E
33°E
30°S
27°S
28°S
31°E
NDUMO GAME RESERVE
NDUMO
TEMBE ELEPHANT PARK
Kosi Bay
Lake Kosi
Black Rock
GREATER ST LUCIA WETLAND PARK
Lake Sibayi
Sodwana Bay
Lake St Lucia
Cape Vidal
ST LUCIA ESTUARY
MKUZE
HLUHLUWE
HLABISA
KWA MBONAMBI
NSELENI
EMPANGENI
FELIXTON
RICHARDS BAY
786
779
771
677
790

Glossary of Selected Scientific and Vernacular Terms

Michael C. Rutherford, Ladislav Mucina, Leslie W. Powrie, Robert A. Ward and Freddie Ellis

Introduction

This glossary contains terms, abbreviations and very widely used vernacular names of plants specific to southern African botanical and geographical terminology, and it is aimed at university and other students and at interested southern African amateur biologists and nature lovers. Professional botanists will benefit from definitions of many of the nonbiological terms used in our book—especially those related to geology, soil, climate, GIS terminology and botanical terms not particularly familiar in South Africa, Lesotho and Swaziland. Some 'endemic' local terms such as those related to landscape (koppie, donga etc.) and biota (bushveld, strandveld etc.) are included. Almost all terms have been extracted from the text of this book.

Many of the terms are referenced. Most soil terms and definitions relate to Van der Watt & Van Rooyen's (1995) glossary. The terms not referenced are our original definitions.

Glossary

Adamellite (geology) Type of granite containing a calcium-bearing plagioclase and a potassium feldspar in roughly equal amounts (Whitten & Brooks 1972).

Aeolian (soil) Wind-borne. Aeolian material is moved by wind rather than water or by decomposition of local rock. Most aeolian sand is of marine origin, although sand may be dispersed from some rivers by wind (modified after Low & Rebelo 1998).

Afromontane (biogeography) Pertaining to regions of high altitudes in the mountains of Africa. Sometimes used interchangeably with 'afrotemperate'.

Afrotemperate (biogeography) Pertaining to regions in Africa characterised by temperate climate, usually found at higher altitudes (East African mountains, Drakensberg).

Agg. (taxonomy) Abbreviation of 'aggregate'. A neutral taxonomic category designating a group of morphologically very similar plant taxa that are often confused, e.g. in field studies. In our book this term is used interchangeably with 'complex', another auxillary taxonomic category.

Agrestal (vegetation) Pertaining to vegetation of weeds infesting arable land, synonymous with 'segetal vegetation'.

Alluvium (geology, soil) Sedimentary material found in regions fringing river courses and composed of detrital matter transported and deposited by the river.

Amphibole (geology) Any of a class of rock-forming silicate and aluminosilicate minerals with fibrous or columnar crystals (Thompson 1995).

Amphibolite (geology) A metamorphic rock composed mostly of amphibole minerals (Whitten & Brooks 1972).

Andesite (geology) A fine-grained volcanic igneous rock of composition intermediate between basalt and rhyolite, characterised by the presence of oligoclase or andesine (both minerals with more sodium than calcium in their composition) plagioclase feldspar (after Whitten & Brooks 1972).

Anorthosite (geology) A coarse-grained plutonic igneous rock consisting of more than 90% plagioclase feldspar, the plagioclase being generally calcium-rich (Whitten & Brooks 1972). In South Africa, the Bushveld Igneous Complex contains many anorthosite layers formed by the cyclic fractional crystallisation from a gabbroic magma.

Apedal (soil) Pertaining to a soil having no visible internal structure (after Low & Rebelo 1998).

ARC/INFO® (GIS terminology) Name of software package made by Environmental Systems Research Institute, Redmund, California, for geographic information system (GIS) analysis. ARC/INFO is used worldwide by thousands of different organisations for handling, managing and analysing geographical information.

ArcView® (GIS terminology) A geographic information system (GIS) software package made by Environmental Systems Research Institute with many of the features of ARC/INFO.

Arenite (geology) A broad term describing detrital sedimentary rocks, typically sandstone, of a particle size between 1/16 mm and 2 mm (Whitten & Brooks 1972).

Argillaceous (geology) Pertaining to a group of detrital sedimentary rocks, including clays, shales, mudstones and siltstones. Two grades of particle size are recognised, namely silt (from 1/16 mm to 1/256 mm) and clay (less than 1/256 mm). The rocks are composed of clay minerals and finely divided quartz and carbonates (Whitten & Brooks 1972).

Asteraceous (vegetation) Pertaining to vegetation dominated by members of the daisy family (Asteraceae or Compositae), e.g. asteraceous fynbos.

Banded ironstone (geology) Also known as jaspilite; a banded rock composed of alternating layers of iron oxide and jasper, a red variety of chalcedony (cryptocrystalline variety of SiO_2). These rocks are chemical sediments deposited due to increased oxygen contents of a body of water precipitating dissolved iron in a cyclic nature. Huge iron ore deposits are found in South Africa in the Banded Iron Formation (Transvaal Supergroup).

Basalt (geology) Generally fine-grained dark-coloured volcanic igneous rock, composed primarily of calcic plagioclase and pyroxene, with or without olivine.

Batholith (geology) Term applied to very large bodies of intrusive igneous rock and generally composed of many smaller plutons. The term is most commonly used to describe granitic bodies.

Berg wind (climate) A katabatic (downslope and generally offshore) wind of especially the West and South Coast of South Africa, which is both hot and dry and therefore conducive to spread of fire (Low & Rebelo 1998).

Biodiversity (biology) The sum of all taxa of animals, plants, fungi and micro-organisms as well as their communities in a region (modified after Low & Rebelo 1998).

Biome (biology) A broad ecological spatial unit representing major life zones of large natural areas, and defined mainly by vegetation structure, climate as well as major large-scale disturbance factors (such as fire) (after Low & Rebelo 1998).

Biotite (geology) Dark-coloured tri-octahedral mica common in igneous and metamorphic rocks (Deer et al. 1992).

Bog (soil) An area of swampy ground generally with a layer of organic matter (peat).

Broken veld (geomorphology) A region characterised by rugged topography, preventing easy thoroughfare. The granitic landscapes of the Succulent Karoo are good examples (Low & Rebelo 1998).

Bushveld (vegetation) A local regional term translated from the Afrikaans 'bosveld' and generally applied to various forms of savanna vegetation south of the miombo belts in southern Africa. In regional terms (Central Bushveld), used for the elevated plateaus between Pretoria in the south and Limpopo River in the north.

Butt (geomorphology) Solitary, usually pointed hill with hard capping on the top, rising above surrounding flat landscape; often occurring in the Karoo. Often spelt 'butte' (from the French) and mainly applied in the western USA.

C_3 (plant physiology) A photosynthetic system in which Calvin Cycle photosynthesis occurs in both bundle sheath and mesophyll cells in the leaf. The name is derived from the initial fixing of CO_2 in three-carbon chain compounds.

C_4 (plant physiology) A photosynthetic system in which the initial fixing of CO_2 is via a four-carbon chain compound. These species have the Calvin Cycle photosynthesising cells concentrated around the vascular bundles (Kranz anatomy), whereas the cells elsewhere in the leaf specialise in absorbing CO_2 from the atmosphere. C_4 photosynthesis is more efficient than C_3, at higher light intensities and higher temperatures, hence its prominence amongst grasses (and other plant species) in the warmer, summer-rainfall regions (after Low & Rebelo 1998).

Calcareous (geology, soil) Pertaining to a soil or rock containing calcium carbonate, or related minerals, so that it effervesces (bubbles of CO_2) when treated with acid. Usually formed from shells or chemical precipitation, these soils and rocks tend to have a coastal distribution (modified after Low & Rebelo 1998).

Calcrete (geology) A rock formed in the soil profile at the water table when calcium carbonate accumulates and cements particles together to form a hard rock band (Low & Rebelo 1998).

CAM Abbreviation of 'Crassulacean Acid Metabolism' (plant physiology). A photosynthetic system found in many succulent plants whereby carbon fixation takes place at night (as opposed to daylight in C_3 and C_4 plants) when lower temperatures reduce the rate of water loss during CO_2 uptake through the stomata. A very strong form of CAM is referred to as CAM idling where stomata remain closed by day and night when there is an internal recycling of nocturnally refixed respiratory CO_2 usually in response to severe stress due to limitations of water availability. CAM cycling is yet another (weak) form of CAM metabolism with C_3 photosynthesis occurring throughout the light period (Lüttge 2004).

Cambic B-horizon (soil) A subsurface horizon containing illuvial clay, humus, or amorphous sesquioides, but not in sufficiency to be classed as spodic or argillic.

Cambisol (soil) Young soil with a cambic B-horizon and a A-B-C profile. Cambisols are typical in temperate or cooler regions, in which soils are either young or, depending on the climate, in which processes of soil formation occur slowly.

Cape Floristic Region (CFR) (biogeography) One of 37 global floristic regions (phytochoria) as defined by Takhtajan (1986), often referred to as the Cape Floristic Kingdom (CFK) which is one of six global floristic kingdoms.

Catena (soils) A related sequence of soil profile types created by changes from one drainage condition to another. These changes are usually transitional. Common example is from hilltop to valley bottom.

CE (biogeography) Abbreviation of 'Centre of Endemism' (see also Van Wyk & Smith 2001).

Chert (geology) Cryptocrystalline quartz of organic or inorganic origin. Also, the rock formed by the precipitation of this material, which can form bands or layers of nodules in sedimentary rocks (modified after Whitten & Brooks 1972).

Chlorite (geology) Green, flaky mineral of variable composition that is a common alteration product of ferromagnesian minerals; structurally resembling the micas (Deer et al. 1992).

Clastic (geology) Consisting of fragments of rock or of organic structures that have been moved individually from their places of origin (American Geological Institute 1976).

Climax (vegetation) That vegetation type or plant community structure that occurs at the end of the seral cycle. The climax communities may not be the final end point of the succession: frequent or even rare events, such as fire, frost, harvesting, or hurricanes, may hold the communities in a stable subclimax indefinitely (Low & Rebelo 1998).

Cobbles (geology) Generally rounded rock fragments with a diameter of between 64 mm and 256 mm, i.e. larger than a pebble and smaller than a boulder (Whitten & Brooks 1972).

Conglomerate (geology) A sedimentary rock type consisting of rounded pebbles (> 2 mm) or small rocks cemented with sands, silts or clays into a solid rock (Low & Rebelo 1998).

Coverage (GIS terminology) ARC/INFO data format of a digital spatial data set.

Craton (geology) Old, rigid, stable block of continental crust consisting mostly of coarse crystalline granitic rocks. Southern African geology has been dominated by the Kaapvaal Craton which has remained largely unaffected by several orogenic events along its fringes for the past two and a half billion years.

Cross-walk (analysis) A matrix table which usefully gives the degree of spatial correspondence between two mapped layers of information. A cross-walk represents one feature type as columns to compare with intersections with another feature represented as rows.

Cupressoid (botany) Pertaining to plants with small, awl-shaped leaves which clasp the stem, resembling those of a cypress (Low & Rebelo 1998).

Datum (GIS terminology) A set of parameters and control points used to accurately define the three-dimensional shape of the earth (e.g. as a spheroid). The datum is the basis for a planar co-ordinate system. VEGMAP uses the internationally related Hartebeesthoek94 datum based on the World Geodetic System 1984 (WGS84) reference ellipsoid. This replaces the previously used Cape datum.

DEAT (institution) Abbreviation of the national 'Department of Environmental Affairs and Tourism', a ministry of the Government of the Republic of South Africa.

Decimal degrees (geography) Degrees of latitude and longitude expressed in decimal format rather than in degrees, minutes and seconds.

DEM (GIS terminology) See 'Digital elevation model'.

Diabase (geology) An ambiguous term used synonymously with dolerite. Other applications of the word are falling into disuse.

Diamictite (geology) A conglomerate with relatively few clasts (pebbles), such that they are not touching and forming a supporting network. A matrix of finer material surrounds and supports the clasts (Boggs 1992). Glacial deposits are often diamictic.

Digital elevation model (GIS terminology) Cell-based, common digital data of the shape of the earth's surface (ESRI 2006).

Digitising (GIS terminology) Transforming map features into digital form. Usually accomplished with a digitising tablet, or by creating a digital version and georectifying an image.

Diorite (geology) A coarse-grained plutonic igneous rock of a composition intermediate between granite and gabbro. It is the plutonic equivalent of andesite.

Dithionite (soil) As sodium dithionite (together with sodium bicarbonate and sodium citrate) an extracting reagent used for the determination of 'free' aluminium and iron in soils.

Dolerite (geology) An igneous rock with fine to medium grains, consisting of equal quantities of the minerals feldspar and pyroxene. Chemically, it is the same as basalt and gabbro. During the Jurassic Period, enormous quantities of dolerite were injected into the Karoo Sequence deposits as vertical dykes and horizontal sills. Because of its resistance to erosion, dolerite dykes and sills have shaped many landscapes, especially the eastern Karoo (Low & Rebelo 1998).

Dolomite (geology) A carbonate of calcium and magnesium, which only effervesces with dilute acid if powdered or heated. The Transvaal Supergroup comprises much dolomite, formed by chemical precipitation. Dolomite dissolves giving rise to sinkholes (as in Gauteng), but also stores water, giving rise to the 'eyes' (small lakes) in North-West Province (modified after Low & Rebelo 1998).

Donga (geomorphology) Local term for deep, usually dry erosion trench or ravine.

Dorbank (soil) A hard to extremely hard (silica-cemented) layer of soil. It occurs as a (usually reddish coloured) subsoil horizon in certain soils of arid regions. It does not slake in water but only in strong alkali. It is synonymous with the 'duribank' (or 'duripan') of other classification systems.

Doringveld (vegetation) Afrikaans term for vegetation (usually woodland) dominated by *Acacia* (for example *Acacia karroo*).

Duplex (soil) A soil type with a porous topsoil abruptly overlying a slowly permeable layer of soil, usually sand over clay. This does not apply to hardpan layers which form within a soil type due to cementing by iron oxides (ferricrete, laterite), silica (silcrete) or lime (calcrete) (after Low & Rebelo 1998).

Duribank (soil) Synonymous with 'dorbank' or 'duripan'.

Duricrust (soil) A hard crust that formed near the land surface during the processes of weathering of rocks and during soil formation, usually in tropical or arid regions. The main types include alcrete, calcrete, ferricrete (laterite) and silcrete.

Duripan (soil) A term used in certain international classification systems for a mineral soil horizon that is cemented by silica to a point that air-dry fragments will not slake in water or HCl; synonymous with 'dorbank'.

DWAF (institution) Abbreviation of the national 'Department of Water Affairs and Forestry', a ministry of the Government of the Republic of South Africa.

Dystrophic (soil) Pertaining to soil that has suffered marked leaching of the exchangeable basic cations (i.e. Ca, Mg, K and Na). Such soils are generally referred to as having a low base saturation. Synonymous with dystric.

Ecotone (vegetation) A zone in which two or more vegetation types or ecosystems merge. These areas may be rich in species from both systems, or may occur as species-poor fringes (Low & Rebelo 1998).

Eluvial (soil) Pertaining to weathered material which is still at, or near, its point of formation (Whitten & Brooks 1972).

Endemic (biogeography) Pertaining to a plant or animal species which is naturally restricted to a particular, well-defined region. This is not the same as the medical definition, which is 'occurring naturally in a region'—it is thus often confused with indigenous (modified after Low & Rebelo 1998).

Ephemeroid (botany) Referring to the life-form of a perennial plant that makes occasional appearances above-ground and maintains perennating organs underground (e.g. bulbous plants).

Epiphyte (botany): A plant which grows on another plant, but which is not parasitic and uses the other plant only as a perch for better obtaining light or nutrients (Low & Rebelo 1998).

Eutrophic (soil) Refers to soil that has suffered little or no leaching of the exchangeable basic cations (Ca, Mg, K and Na). Such soils are generally referred to as having a high base status.

Feldspar (geology) A group of the most abundant minerals in the earth's crust. Most can be classified as members of the simple ternary system albite–potassium feldspar–anorthite (after Deer et al. 1992).

Ferricrete (geology) A rock formed in the soil profile at the water table when iron oxides accumulate around and cement grains together to form a gravelly or nodule-rich band. This may become impervious to water (compare 'Duplex'). Also known as 'ironpan', 'koffieklip', 'ouklip' or 'ngubane' (modified after Low & Rebelo 1998).

Fjelfield (vegetation) Open-canopy, low vegetation composed of herbs, dwarf shrubs, mosses and lichens on shallow stony soils in the (sub)antractic and (sub)arctic regions. Also spelt fellfield.

Floristic (vegetation) Referring to the use of plant species composition (flora) as criterion for characterising or classifying vegetation.

Forb (botany) A plant without secondary thickening (i.e. non-woody), usually living for only one or two seasons (Low & Rebelo 1998).

Forest (vegetation) A plant community having a continuous tree layer, with or without a shrub/herbaceous layer (Geldenhuys et al. 1988). In his structural classification of vegetation types, Edwards (1983) defined forest as a 'vegetation type possessing canopy cover ≥ 75% of trees taller than two metres'.

Fynbos (biome) Large areas of Western (and partly also Northern and Eastern) Cape Provinces, characterised by a predominantly winter-rainfall regime and supporting shrublands, herblands, grasslands and restiolands. These can be (in some

cases partly) structurally classified as fynbos, renosterveld, strandveld and Cape thicket.

Fynbos (vegetation) The dominant vegetation of the Fynbos Biome, characterised by the presence of Restionaceae, and often with a high cover of ericoid shrubs in the families Ericaceae, Asteraceae, Rhamnaceae and Thymelaeaceae, and the common occurrence of Proteaceae. It occurs predominantly on nutrient-poor soils.

Gabbro (geology) A dark, coarse-grained igneous rock, consisting of the mineral calcium-feldspar and crystals of the pyroxene group (olivine may be present). It is the plutonic equivalent of basalt and dolerite (modified after Low & Rebelo 1998).

Geodatabase (GIS terminology) A logical collection of interrelated information managed and stored as a unit, usually on some form of mass storage system such as magnetic tape or disk. A GIS database includes data about the spatial location and shape of geographical features recorded as points, lines, areas, pixels, grid cells or TIN (Triangular Irregular Network) as well as their attributes (ESRI 2006).

Geogenic mottling (geology) Spots or blotches of colour or shades of colour interspersed with the dominant colour of the soil matrix; developing by weathering of rock consisting of different kinds of minerals.

Geographic Information System (GIS terminology) An organised collection of computer hardware, software, geographical data, and personnel designed to efficiently capture, store, update, manipulate, analyse, and display all forms of geographically referenced information (ESRI 2006).

Geophyte (botany) A plant with its permanent parts in the ground, and of which the aerial parts die back annually. The flowers are produced before, with or after the leaves. Important groups of geophytes include plants with corms, bulbs and rhizomes (underground stems) (modified after Low & Rebelo 1998).

Georeference (GIS terminology) To establish the relationship between page co-ordinates on a planar map or image with known real-world co-ordinates (longitude/latitude). Also referred to as registering or georectifying.

Geoxylic suffrutex (botany) A plant with annual or short-lived woody above-ground shoots sprouting from a massive or extensive, perennial, underground stem (after Low & Rebelo 1998).

Gilgai (soil) The microrelief of soils produced by swelling clays during prolonged expansion and contraction as water content changes resulting in microbasins and microknolls in nearly level areas and small microvalleys and microridges parallel to the direction of the slope.

GIS See 'Geographic Information System'.

Glenrosa (soil) Soil form with orthic A-horizon above a lithocutanic B-horizon.

Gleying (soil) Intense chemical reduction in prolonged waterlogged soils, generally grey (no iron) or blue-green (iron present) (Low & Rebelo 1998).

Gneiss (geology) Banded rocks formed during high-grade regional metamorphism. Gneisses are generally coarse-grained, rich in quartz and feldspar and can form from a number of protoliths (precursor rocks) (modified after Whitten & Brooks 1972).

Graben (geology) A downthrown block between two parallel normal-faults (Whitten & Brooks 1972) that will commonly form a sedimentary basin. A half-graben is a similar structure formed to the downthrown side of a single normal-fault.

Graminoid (botany) Pertaining to a herbaceous growth form characterised by a 'grass-like' appearance (tufted growth, usually long and narrow leaves, secondary root system) and including plants such as grasses, restios, sedges and rushes.

Granite (geology) A coarse-grained igneous rock that is the plutonic equivalent of rhyolite. It consists essentially of quartz, alkali feldspar and mica.

Granodiorite (geology) A coarse-grained plutonic igneous rock, intermediate between granite and diorite.

Granophyre (geology) Very fine-grained granite displaying an intergrowth between quartz and feldspar.

Grassland (vegetation) Vegetation dominated by grasses (or graminoids) usually with a single-layered structure and sometimes with an open, woody plant cover.

Greywacke (geology) Type of arenaceous rock that is usually poorly sorted and contains fragments of rock in addition to an argillaceous (clay-rich) matrix (Whitten & Brooks 1972).

GRID (GIS terminology) A module of ARC/INFO that processes raster data.

Gwarrieveld (vegetation) An Afrikaans term for low shrubland dotted by solitary large shrubs or small trees (especially *Euclea undulata* (gwarrie) and *Pappea capensis*). This type usually occurs on the interface between Karoo and the Albany Thicket in the east.

gya (geology, palaeo-ecology) Abbreviation of 'giga (10^9) years ago'.

Gypscrete (geology) A rock formed in the soil profile at the water table when gypsum accumulates and cements particles together to form a hard rock band.

Gypsum (geology) Common calcium- and sulphur-rich evaporate mineral.

Habitat (environment) The home of any animal or plant species. Generally those features of an area inhabited by an animal or plant considered essential to its survival (Low & Rebelo 1998).

Halophyte (botany) A plant growing in salty environments and able to tolerate high levels of salt contents in the environment (water and/or soil) (after Low & Rebelo 1998).

Hardeveld (geography) A colloquial (Afrikaans) term used to describe a region built of hard-rock geology and often to contrast with adjacent regions with softer, e.g. sandy, substrates.

Hardpan (soil) A layer of strongly cemented material occurring in unconsolidated sediments (or soil profile). Formed by the action of groundwater precipitating a cement (compare 'calcrete', 'silcrete', 'ferricrete', 'gypscrete'); it is synonymous with the term 'duricrust' (Whitten & Brooks 1972).

Headland (geomorphology) A point of high land jutting out into the sea (Thompson 1995).

Hematite (geology) Fe_2O_3, a very important iron-ore found predominantly in sediments or their metamorphic equivalents. Its red streak is characteristic (Deer et al. 1992).

Herbland (vegetation) Structural vegetation type dominated by herbs.

Heuweltjie (geomorphology) Afrikaans term for a raised (sometimes very slightly) mound, about 10–35 m (but mostly

20–30 m) in diameter, which occurs in the winter-rainfall areas of the western Northern Cape and Western Cape Provinces and usually at lower altitudes. These mounds are thought to have been formed by termites. With their higher calcium levels and more clayey soils, they often support distinctive plant communities. Also termed mima-like earth mounds (after Lovegrove & Siegfried 1989, Low & Rebelo 1998).

Hyaloclastite deposits (geology) Deposits of glassy material formed by the eruption of magma (usually basaltic) in a subaqueous environment. This type of rock is most commonly formed at mid-ocean ridges (adapted from Davis & Clague 2003).

Igneous (geology) A rock that forms by the intrusion of magma (plutonism) or the extrusion of lava (volcanism). Plutonic rocks are generally coarsely crystalline (such as granite and gabbro) whereas volcanic rocks are very fine-grained (basalt) or even glassy (rhyolite), although they can contain larger crystals formed at depth before eruption (common in andesite). The other major rock types are sedimentary (deposited by wind and water) and metamorphic (pre-existing rocks transformed by high pressure and temperature).

Illuvial (soil) Referring to a zone of deposition of leached material in a soil or to a soil possessing such zone (modified after Whitten & Brooks 1972).

Indigenous (botany) Occurring naturally in a defined area (contrast with endemic)—the area must be specified. Thus the baobab (*Adansonia digitata*) is indigenous and not endemic to South Africa, but it is not indigenous to KwaZulu-Natal (modified after Low & Rebelo 1998).

Indurated (geology) Hardened. Induration is the process by which soft sediment becomes hard rock due to heat, pressure or cementation (after Whitten & Brooks 1972).

Intertidal (geomorphology) Referring to a complex of coastal and estuarine habitats subject to periodic flooding due to the cyclic ebb and flow movements of the sea.

Intertropical Convergence Zone (ITCZ) (climate) Variable zone around the equator where airstreams from the northern and southern hemispheres converge and characterised by increased convectional activity (intensive air heating) (after Stiegerer 1976).

Kameeldoring (vernacular) Afrikaans word for *Acacia erioloba* (Fabaceae), a conspicuous and important tree of the Kalahari savanna.

Kaolinite (geology) The most important mineral in the kaolinite group of clay minerals. It is a common product of the weathering of feldspar minerals.

Karoo (geography) The arid parts of South Africa but as a geographical term it usually excludes the arid parts of the southern Kalahari and specific areas in the west such as Namaqualand and Richtersveld. However, in terms of biome nomenclature, Namaqualand and Richtersveld are linked to 'Karoo' through the Succulent Karoo Biome.

Karstic (geomorphology) Pertaining to a landscape formed in limestone and dolomite areas characterised by sinkholes and caverns formed by rainwater and groundwater dissolving these carbonate rocks; named for the Karst region of Croatia (former Yugoslavia).

KNP (conservation) Abbreviation of Kruger National Park.

Koppie (geomorphology) Small hill or hillock, an Afrikaans term adopted by South African English.

Lagoon (geomorphology) A stretch of coastal water body, more or less enclosed and separated from the sea by a barrier (usually sand dune cordon) (after Stiegerer 1976).

Land Type (soil) Map unit denoting land, mappable at 1:250 000 scale, over which there is a marked uniformity of climate, terrain form and soil pattern.

Late Glacial Maximum (LGM) (climate) A period during the latest glacial cycle approximately 18 000–20 000 years ago characterised by lower temperature (on average about 6°C lower than today) and drier climate in the eastern part of southern Africa. The winter-rainfall part of the region is supposed to have been wetter during the LGM than today.

Laterite (geology) A residual deposit of hydrated iron oxides formed under special climatic conditions in tropical and subtropical climates by leaching of the rock by groundwater (after Whitten & Brooks 1972).

Latosols (soil) A general term in tropical pedology for soils that have reached a fairly advanced stage of lateritic weathering (Soil Classification Working Group 1991).

Leptosols (soil) A major group of soils described in the World Reference Base for Soil Resources. It defines shallow, stony or very stony soils overlying rock, partially altered rock or strongly calcareous material.

Leucocratic (geology) Pertaining to igneous rocks consisting mainly of light-coloured minerals (quartz, feldspar, white micas etc.). Such rocks often appear dark in hand specimens, but the leucocratic nature is revealed in thin-section (Whitten & Brooks 1972).

LGM (climate) See 'Late Glacial Maximum'.

Liana (botany) Plant with long dangling stems, with roots in the ground and leafy parts in the canopy, usually supported by the branches of trees (after Low & Rebelo 1998).

Lithocutanic B-horizon (soil) A South African Soil Classification diagnostic subsoil horizon. It has distinct affinities with the underlying parent rock into which it merges. It has a cutanic character usually expressed as tongues of prominent colour variegations.

Lithosol (soil) A shallow soil, comprising mostly bedrock or rock fragments, some weathered.

Lowveld (geography) South African word, originating in both Afrikaans and English, for 'low-altitude veld'; encompassing the specific areas between the Eastern Escarpment and the Lebombo Mountains in Limpopo and Mpumalanga Provinces, the northern interior lowlands of KwaZulu-Natal as well as the lowlands of Swaziland and southeastern Zimbabwe. The term is never used to apply to the coastal lowlands.

Mafic (geology) Pertaining to ferromagnesian minerals (rich in iron and magnesium). It is often used to describe rocks rich in these minerals although, strictly, melanocratic is the correct term (Whitten & Brooks 1972).

MAP (climate) See 'Mean annual precipitation'.

Map scale (geography) The reduction needed to display a representation of the earth's surface on a map usually expressed as a fraction of the measure on the map over the equivalent measure on the earth's surface (e.g. 1:50 000). A common error is to confuse the geographical terms 'larger' and 'smaller' scales. Large-scale maps such as 1:50 000 show great detail, whereas smaller scale maps such as 1:250 000 show few details but large areas, i.e. maps covering broader areas and usually with less detail are at a smaller scale.

Marula (ethnobotany) Adaptation of the Setswana and North Sotho 'morula' name, possibly via Afrikaans 'maroela', for *Sclerocarya birrea* (Anacardiaceae), popular native fruit tree, characteristic of many types of savanna vegetation in Africa.

MAT (climate) See 'Mean annual temperature'.

Mean Annual Precipitation (MAP) (climate) Arithmetic mean of the precipitation at a locality over many years. Differs from median annual precipitation, which is the middle value of precipitation, with the number of years with higher precipitation equalling the number of years with lower precipitation. In southern Africa the number of years below average are more numerous than those above average (especially in areas of low rainfall), and therefore median annual precipitation is sometimes preferentially used to reduce risk in planning within precipitation-dependent enterprises such as farming (Schulze 1997). The median values thus provide some form of statistical expectation. Sometimes mean and median values are very similar.

Mean Annual Temperature (MAT) (climate) The temperature of the whole year arithmetically averaged over many years at a locality. In South Africa, where hourly data are generally unavailable, MAT is approximated by averaging all the daily maximum and minimum temperature values of each year. In South Africa the error is always in the form of a small (typically around 0.5°C) overestimate. Temperatures are measured in well-ventilated shade (typically Stevenson screens) and at a height of 1.2 m above ground, which can greatly overestimate (i.e. less cold) winter minimum temperatures near the ground surface.

Median Monthly Precipitation (climate) The middle value of precipitation for a given month from those of each year ranked from highest to lowest for a locality. Mean monthly precipitation values are frequently 'inflated' by a few heavy and extreme events (especially in dry regions) while the median values are more representative of expected conditions which are important for planning in enterprises such as farming (Schulze 1997). Sometimes mean and median values are very similar.

Mekgacha (geomorphology) SeTswana word for 'dry river canal'; similar to Herero 'omuramba', American 'river wash' or Arabic 'waadi'.

Melanocratic (geology) Pertaining to igneous rocks consisting mainly of dark minerals (Whitten & Brooks 1972). 'Melanic' means 'dark'.

Mesa (geomorphology) A flat-topped hillock or small mountain, formed for example by a hard sandstone sheet or dolerite sill capping that protects the underlying softer rock from erosion. Mesas and the smaller butts (sometimes eroded to a striking pinnacle) are typical of many Karoo landscapes (Low & Rebelo 1998).

Mesic (soil, habitat) Intermediate between dry and wet in either climate or soil water characteristics (Low & Rebelo 1998).

Metadata (GIS terminology) Information about GIS data describing a collection of data. Metadata for geographical data may include the source of the data, their creation date and format, their projection, scale, resolution, and accuracy, and their reliability with regard to some standard. Metadata consist of properties and documentation. Properties are derived from the data source, while documentation is entered by a person. By default, ArcCatalog automatically creates and updates metadata, which are stored as well-formed XML data in a file alongside the data or within a geodatabase. Metadata for a folder can also consist of a well-formed HTML file describing its contents (ESRI 2006).

Metasediment (geology) Metamorphosed sedimentary rock.

Metavolcanic (geology) Pertaining to metamorphosed volcanic rock.

Middleveld (geography) A term very commonly used in Swaziland for the area between the highveld and lowveld, i.e. roughly between altitudes of 400 and 800 m. In South Africa rarely used to describe the plains between the highveld and lowveld, essentially the area north of Pretoria and west of the Eastern Escarpment. In KwaZulu-Natal this intermediate area is referred to as the midlands.

Midlands (geography) Local term designating a mid-altitude area of KwaZulu-Natal.

Mielie (vernacular) Afrikaans word for maize (*Zea mays*).

Migmatite (geology) Essentially it is any 'mixed' rock. Usually used to describe a rock that has formed by partial melting. This results in a rock consisting of leucocratic material mixed with melanocratic material. The leucocratic material represents a former melt segregated from a residuum of mafic material, the melanocratic part.

Miombo (vegetation) Tropical savanna vegetation typical of Zimbabwe, Zambia, Mozambique, Malawi, southern Tanzania, southern Democratic Republic of Congo and Angola, and dominated by ceasalpinioid trees of the genera *Brachystegia*, *Julbernardia* and *Isoberlinia*. Ranging from sparse woodlands to closed-canopy deciduous miombo forests.

Mire (habitat) A peat-forming ecosystem also called 'bog' or 'flush'. Does not include marshes since they are not peat-forming.

Mispah (soil) Soil form with orthic A-horizon above hard rock.

Mistbelt (geography) Variable altitudinal belt with high frequency of mist and fog resulting from precipitation of water-laden ascending airflows. Mistbelt occurs over much of the KwaZulu-Natal midlands and Northern Escarpment.

Mollisol (soil) One of the soil orders of the USDA Soil Taxonomy. It describes soils of subhumid to semi-arid grasslands with deep, dark, friable surface horizons, with a moderate to high base saturation.

Montmorillonite (soil) Clays with a 2:1 lattice arrangement, found mainly in fertile soils. They store water extremely well (Low & Rebelo 1998).

Mopane (vegetation) Type of savanna woodland, usually dominated by mopane trees or shrubs (*Colophospermum mopane*, Fabaceae), occurring on heavy soils on broad alluvia over large stretches of the Lowveld (Limpopo Province), Zimbabwe, Botswana, Zambia, northern Namibia, southern Angola, parts of Mozambique and southern Malawi.

Muthi (ethnobotany) Nguni word for plants (or animals or minerals) or parts thereof used in traditional African medicine (Low & Rebelo 1998).

mya (geology, palaeo-ecology) Abbreviation of 'million years ago'.

Neocarbonate B-horizon (soil) A South African Soil Classification diagnostic subsoil horizon. It describes a horizon that has developed in recent sediments and unconsolidated material (usually transported), showing little signs of pedogenesis and is calcareous.

Neocutanic B-horizon (soil) The noncalcareous equivalent of the neocarbonate B-horizon.

Ngongoni veld (habitat) Type of wiry grasslands (usually secondary) in overgrazed coastal areas of Transkei and KwaZulu-Natal and dominated by *Aristida junciformis*. The word is the Nguni name of this grass species.

Norite (geology) A type of gabbro (see 'Gabbro').

Oligotrophic (soil) Poor in nutrients (see also 'Dystrophic').

Orogen (geology) Mountain belt, or the exposed core of such a belt after erosion has reduced the relief.

Orogeny or orogenesis (geology) The process of forming mountains, particularly by folding and thrusting (American Geological Institute 1976). Also the period of mountain building. Duration generally several tens of millions of years (Whitten & Brooks 1972).

Orthic A-horizon (soil) A South African Soil Classification diagnostic surface horizon. It is the most widely distributed surface horizon in South Africa and describes a surface horizon that does not qualify as organic, humic, vertic or melanic topsoil horizons.

Ortstein (soil) A massive soil material (hardpan) enriched with and strongly cemented by iron oxides and organic matter.

Palmveld (vegetation) Fairly limited wetland areas in Maputaland characterised by wet grasslands with patches of generally low *Phoenix reclinata* and dotted with iLala palm (*Hyphaene coriacea*) occurring as solitary trees or in small groups.

Pediment (soil) The flat area at the foot slope of a mountain or hill (Low & Rebelo 1998).

Pedocutanic B-horizon (soil) Horizon with a moderate to strong blocky structure and clearly expressed cutans.

Pedologic (soil) Referring to soil. Pedology is the science of the soil.

Phreatomagmatic activity (geology) Volcanic activity caused by the rapid and violent conversion of groundwater to steam as a result of some magmatic heat source (Whitten & Brooks 1972).

Phyllite (geology) A cleaved metamorphic rock coarser-grained than slate, but finer-grained than mica schist (Whitten & Brooks 1972).

Physiognomy (vegetation) The structure and life form characteristics of a particular plant community or vegetation type (Low & Rebelo 1998).

Phytochorion (plural 'phytochoria') (biogeography) Unit of phytogeographic classification of land, usually based on the co-occurrence (as well as striking absence) of groups of plant taxa. Floristic kingdom, floristic region, floristic province etc. are categories of phytochoria.

Placic pan (soil) A thin dark cemented layer, more or less parallel to the soil surface, associated with podzol B-horizons. It is commonly cemented with iron oxides and is slowly permeable or impermeable to water and roots.

Plagioclase (geology) One of the most common rock-forming minerals. A mineral series showing a complete compositional variation between sodium-rich plagioclase (albite) and calcium-rich plagioclase (anorthite) (American Geological Institute 1976).

Playa (geomorphology) Dry lake bed in desert area. It is synonymous with 'dry salt pan' or 'vloer'.

Plinthic B-horizon (soil) A mottled and concretionary (iron and manganese oxide) horizon that is nonindurated and noncalcareous (soft plinthic). The hard plinthic B is the indurated equivalent of the soft plinthic B.

Pluton (geology) In the strictest sense, a body of igneous rock that has formed below the surface of the earth by consolidation from magma (American Geological Institute 1976).

Podzol (soil) A soil in which the minerals (especially iron), clay and organic matter, have been leached out, giving rise to a white middle layer (an E-horizon). This typically occurs in soils derived from quartzitic sands under acidic conditions (after Low & Rebelo 1998).

Polygon (GIS terminology) A two-dimensional multisided enclosed area representing any feature.

Prismacutanic B-horizon (soil) Horizon with an abrupt transition with respect to texture, structure or consistence. The structure is moderately to strongly prismatic or columnar.

Projection (GIS terminology) A mathematical formula that transforms feature locations between the earth's curved surface and a map's flat surface. Projections cause distortions in one or more of these spatial properties: distance, area, shape and direction (ESRI 2006). The VEGMAP wall map and atlas are projected using Albers Equal Area while the electronic data are presented in geographical co-ordinates (decimal degrees). Common projections in use for South Africa are Transverse Mercator for local authority level, Albers Equal Area or Gauss Conform for work on national scale.

Proteoid (vegetation) Vegetation-structural term used to designate fynbos shrublands dominated by the members of the family Proteaceae (such as the genera *Protea*, *Leucadendron*, *Leucospermum*).

QDS (cartography): 'Quarter degree square' comprising the area covered by one map sheet of the 1:50 000 South African topographic map sheet series. Each sheet depicts the area of one quarter degree latitude by one quarter degree longitude and approximates an area of 30 by 30 km. The QDS system was used extensively for designating the distribution of plants in the PRECIS database but more precise GPS co-ordinate recording of specimens is now encouraged.

Quartz patch (geology, soil) Usually arid or semi-arid habitat characterised by concentrations of quartz stones on the surface and in the upper soil layers. Often relatively cooler than surrounding vegetation and generally dominated by succulent 'stone-plants', many of which are endemic.

Quartzite (geology) Strictly it is a metamorphosed sandstone. During heating the constituent grains recrystallise to an interlocked texture, with little or no trace of cementation (modified after Whitten & Brooks 1972). Quartzite is commonly used to describe very pure, well-cemented sandstones of the Cape Supergroup.

Raster data (GIS terminology) Raster data record spatial information in a regular grid or matrix organised as a set of rows and columns (compare 'Vector data').

Reed bed (vegetation) Tall graminoid vegetation composed of reeds (*Phragmites, Typha*), usually found in wetlands.

Regic (soil) Pertaining to a blanket of soil, usually sand, which has been deposited over another soil or rock, and which has not yet had time to develop profiles or layers (after Low & Rebelo 1998).

Regosols (soil) A major group of soils described in the World Reference Base for Soil Resources. Soils with weak or no profile development.

Relational database (analysis) A method of structuring collections of data in tables that are logically associated with each other by shared attributes as opposed to a single table or 'flat table structure'.

Renosterveld (vegetation) An evergreen, fire-prone shrubland or grassland of the Fynbos Biome dominated by small, cupressoid-leaved, evergreen asteraceous shrubs (principally Renosterbos *Elytropappus rhinocerotis*) with an understorey of grasses and a high biomass and diversity of geophytes (Iridaceae, Amaryllidaceae and Hyacinthaceae).

Restioid (vegetation) Pertaining to vegetation dominated by restios (graminoid plants of the family Restionaceae), commonly occurring within the Fynbos Biome.

Restioland (vegetation) A vegetation type dominated by the Restionaceae.

Rhyolite (geology) Fine-grained to glassy volcanic rock of a granitic composition. Silica-rich magmas such as these are very viscous and never form extensive flows around vents; instead they erupt explosively and accumulate by pyroclastic flow or ash-fall (modified after Whitten & Brooks 1972).

Riparian (habitat) Referring to habitats in and around rivers.

River wash (geomorphology) Gently sloping area in arid region resulting from flash discharge of precipitation over surface; the habitat is similar to a broad alluvial fan.

Rivier (geography) Afrikaans word for 'river'; in arid regions used for normally dry river courses.

SANBI (institution) Abbreviation of 'South African National Biodiversity Institute', a statutory body falling under DEAT, with its head office in Pretoria, and research, herbaria, environmental education and botanical gardens located around South Africa.

Sandveld (region) Afrikaans word for a region characterised by deep sandy soils; found in Grassland, Savanna and Succulent Karoo Biomes.

Saprolite (soil) Weathering rock in various stages of decomposition. It has a general organisation with respect to colour, structure or consistence that still has distinct affinities with the parent rock.

Savanna (vegetation) Typically vegetation with a grass-dominated herbaceous layer and scattered low to tall trees. It includes the closed woodland and open woodland of Edwards (1983) with a tree cover less than 75% and generally greater than 1%.

Savannoid (vegetation) Pertaining to open wooded grassland structurally similar to savanna, but for climatic reasons not belonging to the Savanna Biome. Savannoid vegetation is encountered within temperate zones.

Schist (geology) A regionally metamorphosed rock characterised by a parallel arrangement of the bulk of the constituent minerals. Schist is coarser-grained than phyllite and tends to have undulose cleavage. Mica minerals are generally responsible for the 'schistosity' (Whitten & Brooks 1972).

Sclerophyllous (botany) Referring to plants characterised by hard, woody leaves, which snap rather than bend and posses high carbon to nitrogen ratios, making them unpalatable to browsers. Sclerophyllous plants are typically found on nutrient-poor soils in fynbos (Low & Rebelo 1998).

Scorpionstailveld (vegetation) Type of 'vygieveld' dominated by *Brownanthus pseudoschlichtianus* in or near the Richtersveld.

Seep (habitat) Usually sloping area temporarily (or permanently) waterlogged by groundwater seeping through to the surface. Small water springs develop in places.

Seral (vegetation) Pertaining to a stage in the natural progression of colonisation by plants from bare soil to climax vegetation. Even within climax vegetation, tree falls and other events result in a progressive series of stages (Low & Rebelo 1998) (see also 'Succession').

Serpentine (geology) A group of ultramafic rocks (including hartzburgite, peridotite, phonolite, gabbro, norite etc.) characterised by high magnesium-to-calcium ratios and often a high concentration of heavy metals (nickel, chromium, copper).

Silcrete (soil) A conglomerate formed in the soil profile at the water table when silica (SiO_2) accumulates and cements grains together to form a very hard rock layer.

s.l. (botany) Abbreviation of 'sensu lato' (Latin), meaning 'in a broad sense'.

Solonetz (soil) A soil with a thin porous topsoil with a columnar, salty or sodium-rich subsoil (Low & Rebelo 1998).

Sour grass (vegetation) Veld management term for grasses that have very low nutritional value, especially outside the growing season, exacerbated by the withdrawal of nutrients to underground storage organs. They usually have a very low nitrogen-to-carbon ratio which makes them indigestible to livestock.

Sourveld (vegetation) Vegetation dominated by sour grass. Sourveld tends to occur on infertile and acidic soils (after Low & Rebelo 1998).

s. str. (botany) Abbreviation of 'sensu stricto' (Latin), meaning 'in a narrow sense'.

Strandline (habitat) Narrow band on beach recognisable by deposition of sea-borne debris by wave action.

Strandveld (vegetation) A coastal vegetation type within the Fynbos Biome consisting of medium dense to closed shrublands dominated by succulent and sclerophyllous, broad-leaved shrubs. It is the least fire-prone of the vegetation types in the Fynbos Biome and characteristic Fynbos elements are absent, except as an early seral stage known as dune fynbos.

Stratum (plural 'strata') (geology, soil, vegetation) A horizontal layer or set of layers of rock or soil or plants within a plant community (after Low & Rebelo 1998).

Succession (vegetation) A series of stages (compare 'sera') in which different plants and animals colonise an area following some kind of disturbance. The final stage of the succession is called the 'climax', but various disturbances may prevent the vegetation from attaining its potential climax. The Fynbos, Grassland and Savanna Biomes have a 'fire-climax', in which fire prevents the succession from progressing to forest, in suitable habitats (Low & Rebelo 1998) (see also 'Seral').

Supratidal (habitat) Pertaining to flat areas located just above the maximum upper tidal mark, hence outside the direct influence of the tidal regime, but still with saline water or saline deposits present in the soil profile.

Surtseyan tuff cones (geology) Ash erupted from a volcano is called tuff once it has consolidated. Tuff cones form when the ash accumulates around a volcanic vent in a cone. Surtseyan tuff cones refer to those similar to the type locality of Surtsey, an island formed by the accumulation of ash from an initially submarine volcano near Iceland.

Sweet grass (vegetation) Veld management term for grasses that have a high nutritional value during and outside the growing season and hence can also be grazed in winter.

Sweet veld (vegetation) A vegetation type dominated by sweet grasses. This usually occurs on richer, more alkaline soils (after Low & Rebelo 1998).

Syncline (geology) A basin-shaped fold is known as a synform. It is referred to as a syncline if the rock layers defining the structure are younger closer to the core.

Tafelberg (geomorphology) Afrikaans name for 'table mountain', designating some flat-topped mountains; equivalent to 'mesa'.

Terrane (geology) A crustal block or fragment that preserves a distinctive geological history that is different from the surrounding areas and that is usually bounded by faults.

Thicket (vegetation) Very dense vegetation usually formed by low or tall shrubs and some trees.

Thornveld (vegetation) A woodland savanna dominated by trees with thorns, mainly *Acacia* species.

Tillite (geology) A diamictite formed by glacial activity. The ice is able to transport all grain sizes from rock-flour to large boulders and deposit them to form a poorly sorted conglomerate.

TMS (geology) Abbreviation of 'Table Mountain Sandstone'. Quartz-rich, hard sandstone of Ordovician age, named after Table Mountain.

Tonalite (geology) A type of diorite, often defined as having accessory quartz (Whitten & Brooks 1972).

Ultramafic (geology) Pertaining to igneous rocks consisting of ferromagnesian minerals to the virtual exclusion of quartz and feldspar. These rocks are poor in silica and rich in iron and magnesium. They are very dark in colour (highly melanocratic) and also very dense.

Vector data (GIS terminology) Vector data record spatial information as x,y co-ordinates in a rectangular (planar) co-ordinate system. Point features are recorded as single x,y locations. Line features, including the outlines of polygons, are recorded as an ordered series of x,y co-ordinates (ESRI 2006).

Vegetation structure (vegetation) The horizontal, vertical and temporal arrangement of vegetation, i.e. spatially explicit, e.g. layers, patches etc. (see also 'Vegetation texture') (Barkman 1979).

Vegetation texture (vegetation) The composition of the vegetation in terms of species, growth forms, life forms, leaf morphological types, etc. (see also 'Vegetation structure') (Barkman 1979).

Veld (geography) Very broad term for open undeveloped countryside, usually applied in karroid, grassland and savanna areas and less so in fynbos areas and never in forests.

Veld type (vegetation) A well-known delimitation of vegetation types in South Africa carried out by John Acocks (1953) who defined a veld type as 'a unit of vegetation whose range of variation is small enough to permit the whole of it to have the same farming potentialities'.

Vertic (soil) Pertaining to a soil with a blocky structure, which shrinks and swells markedly depending on wetness, due to a high clay content. These soils have a black or dark colour (Low & Rebelo 1998).

Vesicular hardening (soil) See 'Ortstein'.

Vlei (geomorphology, habitat) Afrikaans term for a depression usually filled with water, at least temporarily, to form a lake or a wetland.

Vloer (geomorphology) Literally Afrikaans for 'floor', a term used for a dry pan in Bushmanland. Also often referred to as 'kolk'. Can be well vegetated (e.g. Grootvloer) or bare (e.g. Verneukpan).

Vygie (botany) Afrikaans vernacular name for all succulent members of the family Aizoaceae (formerly known as Mesembryanthemaceae)

Vygieveld (vegetation) A vegetation shrubland type dominated by succulent plants (storing water in their stems and/or leaves), usually vygies.

Wetland (habitat) Areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt. Includes areas of marine water, the depth of which at low tide does not exceed 6 m (RAMSAR Convention 1971, Article 1.1). Also land where the water table is, at least periodically, at or above the land surface for long enough to promote the formation of hydric (waterlogged) soils and the growth of aquatic plants (Rogers 1997).

WGS84 (GIS terminology) Abbreviation of 'World Geodetic System of 1984'. A geocentric datum and geographical co-ordinate system created by the United States military and in worldwide use (ESRI 2006).

White grass (vegetation) Veld management term for (usually) tussock grasses (*Stipagrostis, Aristida*) turning veld into white plains through their conspicuous plumage of hairs on the seeds at the stage of ripening and dispersal.

Woodland (vegetation) See 'Savanna'.

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INDEX

This index contains comprehensive page number entries for the names of all vegetation types and bioregions. The vegetation types and the pages with their main descriptions are shown as **bold text**. Only main occurrences of biomes and larger protected areas, mainly national parks, are included. Geographical features are mainly limited to regional names and some major mountains and rivers. The index includes the captions of figures and headings of tables. Plant taxa are not listed. Terms that appear frequently are either selectively listed or omitted. Terms occurring in the reference lists, credit sections and on the Atlas sheets (chapter 18) are not presented. References to authors are limited to Acocks but are not given for the vegetation description sections.

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